Essays in Intellectual Property Bargaining and Trade

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Essays on Intellectual Property Bargaining and Trade

A thesis presented

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Essays on Intellectual Bargaining and Trade

Abstract

In this dissertation, I present three essays on the dynamics of intellectual property bargaining and trade, particularly of patents. The first essay pressents a game theoretic model examining the sale of intellectual property rights from small inventors with buyers of varying commercialization capacity across intellectual property rights regimes with full and no property rights protection. The essay finds that in Nash equilibrium in both single seller and infinite seller scenarios, sellers generally approach firms with greater commercialization capabilities if property rights are strong, and approach firms with lesser commercialization capabilities if property rights are not protected. The second essay examines the sale of patents from small inventors and entities to firms from 1992 to 2000. I exploit the 1996 Supreme Court case Markman v. Westview Instruments, arguing that patent protection weakened afterwards, to compare patent sales to firms with greater or weaker commercialization capabilities, which I proxy using industrial patent holdings. Using a conditional fixed-effects multivariate choice model, I find that patent sales are more highly concentrated towards firms with weaker patent holdings after Markman. The last essay develops a conceptual model of patent dynamic capabilities for firms, developing several predictions in conjunction with the technology life-cycle model.

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1.1 Introduction

The market for commercial external innovations, i.e. the purchase, license and sale of technologies, is a critical source of value for firms, as it allows firms to gain access to technologies for commercialization or for use in expanding their technical capabilities. A particularly valuable source of such external technology is from individual or small-scale inventors, who also benefit from the market from technology as it grants them additional avenues to capture the value of their innovations beyond self-commercialization.

The bargaining dynamics of inventors or other sellers of intellectual property (IP) with potential buyers is a well-explored topic in the academic literature, beginning with Arrow (1970). Perhaps the primary issue surrounding the bargaining over innovations is the *paradox of disclosure* (Arrow (1962), Anton and Yao (1994)). Assuming the innovator will not commercialize his invention himself, these innovators must typically disclose their ideas in order to credibly signal the value of their invention to potential buyers. However, this paradoxically also renders them liable to expropriation by the very same potential buyers, who can commercialize the technology without adequate repayment. Innovators thus face a difficult problem in securing the best payoff for their invention.

Scholars have suggested several mechanisms by which these small innovators may capture value from their inventions despite this paradox. Innovators can rely on public infrastructure and intellectual property regimes, or on various bargaining strategies in the relative absence of such regimes. Of the latter, a significant strategy was suggested by Anton and Yao (1994), who argue that by threatening disclosure to competing parties, the inventor is able to secure a certain sum from the buyer even when intellectual property rights have been waived. Otherwise, innovators may be able to only partially disclose their invention (Anton and Yao (2002)), although this depends on part upon the nature of the innovation (single technologies, such as a molecule or a windshield wiper mechanism, may be difficult to disclose only partially). Finally, Teece (1986) suggests that in weak appropriability regimes, innovators should invest in complementary assets, although this is generally only viable for innovators that are attempting to commercialize the technology themselves.

The above provides potential solutions for innovators facing a specific static scenario of property rights, technology, and buyers the optimal behavior of a stream of discrete small innovators across different IP regimes is a significant research question, especially when one takes into account a marketplace of heterogeneous, changing buyers. Anton and Yao (1994) provides the reasoning behind how innovators can capture despite the risk of expropriation, but this does not necessarily provide insight into *which* firms the innovator should approach to maximize their return, and how this might change across different IP regimes.

In this essay, we explore this question of optimal innovator bargaining behavior across different IP regimes with heterogenous buyers over time. We develop single and multi-period game-theoretic models for innovator sales in different IP regimes, incorporating insights from the management strategy, in particular the concept of absorptive capacity. Absorptive capacity, pioneered by Cohen and Levinthal (1990) can be understood as the firm's ability to effectively incorporate external technology effectively - an example of a dynamic capability, i.e. the firm's ability to configure and acquire resources to optimally respond to a changing environment (Teece, et al (1997)). By incorporating an element of absorptive capacity into the buyers, we introduce a dynamic element to the market structure - as technologies are purchased and absorbed by firms over time as new inventors appear with different kinds of inventions, the firm's capabilities (including their absorptive capacities) change, presenting a developing market to innovators. Intuitively, this reflects how incorporating and commercializing innovations changes firms, providing funds, assets, and improving their ability to absorb future technology by expanding the firm's knowledge base.

In the model we also consider different types of inventions - major, highly valuable innovations or smaller, incremental ones - to both consider how different types of inventors may approach the market, but also to capture how firms may alter their strategies to capture a steady stream of small inventions or wait for the "big fish." This distinction is related to an influential stream of literature on the lifecycle of innovation, as pioneered by Tushman and Anderson (1986). Tushman and Anderson argued that technology follows a life-cycle of "punctuated" equilibria, where significant, break-through innovations are followed by a stream of less-impactful incremental innovations that develop the primary disruptive innovation without offering further fundamental technological advances.

By considering both heterogeneous, changing buyers and a discrete stream of heterogeneous inventions simultaneously, we are able to capture how firms can alter their strategies over time, and alter their response to the arrival of new technologies based on their own changing characteristics and the value of the invention. The model thus provides insight not only into optimal bargaining strategy for innovators, but also suggests how the market may evolve over time. We model the case with a seller with a valuable IP, which can be categorized as disruptive or incremental. We examine two settings: those with complete property rights (i.e. full legal protection entitling the holder of an IP to monopoly protection of all rents arising from such rights) vs. no property rights (i.e. expropriation is legally allowed, or at least technically feasible) in both single and infinite-period scenarios.

Our primary result is that over time, given a sufficiently low discount rate (that is, value is discounted more significantly by period) we find that sales of intellectual property concentrate in firms with stronger commercialization capabilities in strong property rights settings, and diversifies across the firm with the weaker commercialization capabilities over time in weak property rights settings. The reasoning is as follows: in strong property rights settings, sellers would approach and sell their IP to the firm with greater absorptive capacity as they are able to realize greater levels of return (due to the above-stated assumption on absorptive capacity giving greater commercial returns, as well as full property rights allowing the IP holder full bargaining power) while in weak property rights settings, sellers would approach and sell their IP to the firm with weaker absorptive capacity due to the logic as given in Anton and Yao (1994).

This paper is structured as follows: Section I introduces the research question and provides an overview of the relevant academic literature and the assumptions underlying the theory, Section II develops the game-theoretic model, and Section III provides concluding remarks and a direction for future research.

1.2 Model

1.2.1 One-Period Model

We consider the problem of multiple inventors over time (or a single inventor, in the one period case) selling intellectual property in regimes of varying property rights strength. Weak property rights is defined as the environment in which technologies or invention - when exposed to an entity that does not hold the property right - can be commercialized by the entity without being required to compensate (or only requiring little compensation) the holder of the actual property right. Conversely in strong property rights scenarios, entities cannot commercialize an invention either without the permission of the rights holder, or without being forced to pay compensation or some manner of penalty afterwards.

In both cases we consider the situation of two heterogeneous buyers - a leader and a laggard. Intuitively, the leader and laggard captures several factors - rather than just market leadership, the leadership positions captures advantages in technical and commercialization ability. Consequently, when given a technology, the leader can earn higher profits than the laggard not only due to an advantageous market position but also due to its inherent abilities, processes, or assets that allow it to quickly and effectively commercialize a technology. Further, due to its greater technical resources and capabilities, the firm derives greater technological benefits from commercializing the new invention, leaving it in an even stronger position afterward. As such, the ability to absorb technology and the ability to commercialize inventions are related, and we model this connection by having firms with greater absorptive capacities also able to realize higher returns from technology.

The correlation of commercialization and absorptive capacities is supported by several streams of literature. Access to a greater range of resources, such as an extensive knowledge base encompassing various valuable technologies, can enhance absorptive capacities (Argote et. al (2003)). Firm assets and commercialization ability also support internal R& D capability, which in turn enhances technological absorptive capacity (Veuglers and Cassiman (2002)). Firm size and scope also reduces search costs.

The above assumptions captures a heterogeneous industry with two firms of separate capabilities. To this framework, we also add heterogeneous innovations.

Each period is defined by the arrival of a new innovation, which can take different values. This captures the uncertainty and the varying value of innovations - that is, some are more valuable than others (as a somewhat extreme example, consider the invention of automobiles versus car seats). Adding this distinction allows firms to capture dynamics whereby some innovations are prized more highly over others and inspire different strategies to capture them.

In this scenario, we consider the arrival of an inventor I with an invention of value V, which can take one of two values $V_B > V_S$. This is treated as a single "period" - the multiple-period model has multiple inventors appearing over time. Intuitively, V_B captures major innovations that a significant impact upon the market, offering higher levels of returns over V_S, which may be thought of as smaller, incremental innovations. Although this distinction will not play a major role in the one-period model, it will become significant in the infinite-period framework. Intuitively we should expect to see incremental innovations occur more frequently than disruptive innovations. This is captured by defining the probabilites of the innovations as $p_B > p_S > 0$, where $p_B + p_S = 1$. We assume that in both scenarios of innovations - big or small - the firm gains a one-time value from commercializing any innovation, and does not benefit from a multi-period incremental stream of profits. The value of the major innovation is simply captured as being larger than the value of the incremental innovation.

Finally, we also assume that the firms have a constant stream of self-invention, from which leaders generate a higher level of returns than laggards. In all cases, due to this stream of self-invention, leaders generate material benefits from being in the leadership position - we include this assumption as otherwise, there would be no benefit to being the "leader" aside from the potential contractual benefits with the stream of outside inventions. However, intuitively, we would expect the leader to have benefits from its leadership position beyond laggard. Mathematically, we describe this by having the leader make $C^H > C^L = 0$ every period. We model $C^L = 0$ for simplicity. This has no effect on the one-period model, as the firm position does not change - consequently, the sale of inventions does not affect the profits of the firm in one period.

We assume that these internal inventions do not interact with the stream of technologies from outside inventors, aside from altering a firm's cabilities. While future research may explore how self-invention can result in innovations that pre-empt the contributions from external innovators, the results would not be significantly altered aside from a redistribution of resources whereby firms may not acquire inventions in certain cases as they have already self-invented, creating a new "starting" scenario where one firm or another is the leader and one already has access to the innovation.

On the other hand, we assume that the inventor cannot self-realize any profit, and therefore must approach one of the two firms to commercialize the innovation and generate some value from his invention. Before the bargaining process, the inventor I must choose between sequential and simultaneous bargaining with the two firms, and also whether to fully reveal the idea to either party in the course of bargaining. Initially, the value of the invention V is only known to the inventor, although the inventor can choose to reveal the invention to a firm, which will also reveal the value of the invention. The inventor chooses which firm to approach (the leader, the laggard, or both). Then, during the bargaining process, the firms employ a private take-it-or-leave-it offer structure for an *ex ante* contract to decide how profits are split after the full payoffs have been realized, and then inventor chooses whether to accept the contract or not. If the inventor does accept the contract, the revelation of the invention or the existence of a contract between I and any of the buyers is public information - that is, if I engages in a contract with a firm, the other firm is aware of this.

The final realized total profits depends on the parameter of the firm, the value of the invention, and the distribution of the ownership of the invention. For instance, if only the market leader is party to an incremental innovation and executes the project, the entire realized profit - which would be exclusive profits as only the market leader has access to the innovation - defined as E_S^H, and if both firms have access, the market leader will make N_S^H (for "non-exclusive"), with profits similarly defined for disruptive innovations and market laggards. We assume that E increases in both the value of the innovation and the market position - that is $E_B^i > E_S^i$ for any i, and $E_j^H > E_j^L$ for any j, and similarly for N.

We additionally assume that $E_S^H > N_k^H + N_k^L$ for all j, k - that is, the exclusive "monopoly" profits always exceed total non-exclusive profits, even if the exclusive profits are for an incremental innovation and the non-exclusive for a major innovation. Future research may explore a situation where non-exclusive profits for a major innovation exceeds the exclusive profits of an incremental innovation, although (as we will see) this primarily has an impact only in the strong property rights scenarios, allowing innovators to execute contracts with both buyers.

We consider two scenarios - full property rights and no property rights.

Full Property Rights

In the full property rights scenario, inventions do not bear any risk of expropriation. That is, even if the inventor reveals his invention to a firm, the existence of a strong property rights regimes protects the inventor, allowing him to claim effective ownership of the all rents arising from commercialization of the protected technologies. Intuitively, this is similar to an industry with strong legal and patent rights, for example the pharmaceutical industry, which is well-known for having strong patent protection for clear, well-defined pharmaceutical compounds. Consequently, the inventor is able to capture a significant proportion of the associated rents of his invention. Further, once a contract has been written between the innovator and a firm, the rival firm is required to write an additional contract with the inventor in order to commercialize the technology itself. However, as the total payoffs from a monopoly case exceed the combined total payoffs of duopoly, writing two contracts will be value-destroying, and thus disadvantageous to the inventor. Thus, in effect we will only see monopoly cases.

After realizing the value of his innovation, I must decide whether to engage in simultaneous or sequential bargaining.

Proposition 1 In the single-period bargaining framework, the inventor I with intellectual property of value V, will accept the leader's offered contract of $E_V^L+\varepsilon$ ex-post (to be paid 0 if non-exclusive scenario results).

Proof. If I chooses sequential bargaining, I must decide which firm to approach first. Suppose I approaches any firm and rejects the firm's offer. I would then approach the second firm - however, knowing that I had approached the first firm but not negotiated a contract, the second firm will offer minimal payoffs - just enough to prevent rejection of the contract - to I, because otherwise I would now earn only 0 profits. Knowing this, the first firm that I approaches will offer I enough to prevent I from rejecting the contract and resulting in the scenario listed above. The firm will thus offer $\varepsilon > 0$ to the inventor, where ε is arbitrarily small, and I will be forced to take the contract as the alternative is to earn another infinitesimally small payoff from the other firm.

However, If I chooses simultaneous bargaining, I will negotiate with both firms at the same time. With complete information, at Nash equilibrium, the market leader will offer $E_V^L + \varepsilon$, and the laggard offer E_V^L with $\varepsilon > 0$ arbitrarily small. In other words, the market laggard will offer up to the full value of profits from commercializing the invention - as the alternative would be receiving a final payoff of 0 by not commercializing any invention. However, as the market leader has full information and makes higher potential payoffs than the laggard, it will be able to offer a marginally better contract to persuade the inventor to sell the invention to the leader instead. As the market laggard cannot afford to outbid the leader, I will choose the market leader's contract and accept $E_V^L + \varepsilon$.

Thus the final Bayesian Nash equilibrium is I choosing to engage in simultaneous bargaining, and accepting the market leader's offer of $E_V^L + \varepsilon$. ■

Intuitively, as the intellectual property regime provides protection over ownership of the invention even despite exposure, the inventor will benefit most by revealing the invention to both parties and securing the best offer from either firm, essentially in an open bargaining or bidding framework. Without risk of expropriation, the inventor has the leisure to secure his best offer.

No Property Rights

In the no-property rights scenario, inventions bear the full risk of expropriation. That is, if the inventor reveals his invention to a firm, the firm can potentially commercialize the invention without compensating the inventor. Given the assumption of rational actors, we are assuming that firms will expropriate if given the opportunity. Future extensions may incorporate reputational effects, which could discourage that sort of behavior; however, even despite such reputation costs, there are in fact well-documented cases of such expropriation occuring in industry, such as Ford Motor Company's expropriation of Robert Kearns' invention of intermittent windshield wiper systems or industry-wide use of Gordon Gould's lasers without awarding of suitable patents.

The inventor thus must take into account the possibility that his invention will be taken and commercialized without compensation. Again, he decides whether to engage in sequential or simultaneous bargaining. As before, there are two firms, a leader and a laggard, and both firms can have access to technology. There are two situations that can emerge out of the dispersion of technology - either only one firm possesses the technology and competes in a monopoly market, or both firms possess the technology and compete in a duopoly market.

Proposition 2 In the single-period bargaining framework, an inventor I with intellectual property of value V will accept the laggard's offered contract of receiving payoffs of $(N_V^H + \varepsilon, 0)$ in exclusive, non-exclusive cases, respectively.

Proof. If I chooses simultaneous bargaining, then the inventor faces two options. It can either reveal the invention to verify its value - then both firms will have access to the innovation and can commercialize to generate non-exclusive, "duopoly" profits. Alternatively, I can choose to not reveal his invention and engage in bargaining around the expected value of the invention. However, in the case $V = V_B$, I will derive greater profits from pursuing sequential bargaining (as the expected value of V will be less than V_B); consequently, if I does not disclose his invention, he is signaling that his invention is worth V_S. The inventor could then auction the rights and receive $N_S^H + \varepsilon$ from the laggard (to prevent deviation).

If I engages in sequential bargaining, the contracting follows the framework developed by Anton and Yao (1994). Suppose I approaches a firm, reveals the invention, and negotiates a contract. At the outset, it does not seem the firm has any incentive to compensate the inventor for the technology. However, due to the lack of property rights, the inventor can threaten to deviate - i.e., reveal the innovation to the other firm. This would result in the reduction of the first firm's profits from exclusive to non-exclusive levels.

As this would result in a substantial reduction in rents, the first firm will offer an ex-poste contract - i.e. a contract where payoffs are disbursed after the market has been determined to be a exclusive or a non-exclusive market, offering zero in the case of the latter, and sufficient payment in the exclusive case to incentivize the inventor from deviating.

From the second firm's perspective (i.e. the firm that currently does not possess the technology), if only the first firm continues to have access to the technology, the second firm will generate 0 profits. Consequently, the second firm will be willing to offer up to infinitesimally less than the full payoffs it would receive if it also gains access to the technology - that is, the second firm will pay the full non-exclusive profits it would gain if the inventor deviates. The first firm will thus pay slightly more than this amount to prevent deviation.

The second firm will pay N_V^L if it is the market laggard, and N_V^H if it is the leader to encourage the inventor to deviate. Consequently, to prevent deviation, the first firm will pay slightly more than these amounts (which they can afford to do as all exclusive "monopoly" payoffs are greater than non-exclusive duopoly payoffs).

As $N_V^H > N_V^L$, the inventor will earn greater payoff from the first firm preventing deviation if the second firm is the leader. Consequently, the innovator will approach the market laggard for its contract, earning $N_V^H + \varepsilon$ from the laggard if it does not deviate, and N_V^H from the leader if it does deviate - a rational innovator will thus choose not to deviate.[1] ■

Intuitively, the laggard firm will have to pay a greater amount to the inventor as the leader can afford to pay a greater amount to the inventor to deviate and disclose his idea. One can think of the laggard as essentially being forced by its weaker position into paying more to the inventor in an effort to maintain exclusive access to the innovation. Thus, in the Nash equilibrium the inventor will approach the laggard.

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[1] The model is a simplified version of the one contained in Anton and Yao (1994) that does not allow self-invention. As such, we are assuming that the court cannot infer that if a firm uses the invention, the source of the invention was the inventor.

1.2.2 Infinite-Period Model

We extend the model to infinite periods. This better reflects the strategic behavior of firms in the market, who face a stream of inventions instead of a single one. The inventions, when executed, also affects the firm's commercialization ability, either catapulting it into a position of leader or maintaining the firm's current position, depending on the disposition of the technology and the firm's characteristics.

As stated above, there are two types of innovation that appear in the marketplace - large, highly valuable and smaller, incremental innovations. These innovations impact firms in different ways when absorbed and commercialized. In our model, incremental innovations, as suggested by their name, do not significantly impact the firm's characteristics and result in lower payoffs than disruptive innovations. On the other hand, disruptive innovations are significant - not only do they offer higher payoffs from commercialization, developing a disruptive innovations can enhance firms' technical abilities and turn it into the leader in the next period. This gives the firm access to higher payoffs from innovations, both externally and from its own internal stream of innovations.

We model this as follows. When $V = V_S$, when the innovation is commercialized, the characteristics of the firm do not change. That is, if the innovation is commercialized laggard firms remain laggard, and leader firms remain leader. When $V = V_B$, however, laggard firms have the opportunity to become the leader - if the laggard commercializes the technology, it gains enough knowledge and captures enough of the market to become the new leader in the next period (as it requires commercialization to fully absorb the technology and develop the capabilities to become leader). Critically, we assume that firms do not become leaders if they commercialize sufficient incremental innovations. To a certain extent, this reflects how the inventions are very small, but future research would consider how a certain level of incremental innovations can enhance a firm's capabilities to become the leader, introducing the potential whereby a firm can "wait out" large innovations and become the leader by accumulating smaller ones. However, by assuming sufficient "technological decay", as discussed below, a large discout rate, or a relatively small value of the incremental innovations, the assumption is strong, but potentially not unreasonable.

On the other hand, while leader firms do not change their position, although they make an accordingly higher level of payoff from commercializing the invention itself. As leaders, they maintain their leadership position. Intuitively, this reflects "technological decay" - i.e. how after the initial advantage rendered by a disruptive innovation, the competitive advantage erodes as incremental innovations diffuse over time until firms can be again compete equitably after one disruptive innovation. Extensions to the model may explore changing the extent to which leaders can benefit from acquiring a valuable technology, although to a certain extent the advantages can be captured by the difference between E_B^H and E_S^L. If both firms commercialize the disruptive innovation, the leader is able to maintain its competitive advantage and remain the leader in the next period.

A key assumption is that different inventors appear over time, instead of the same inventor re-appearing with new inventions. If the latter were the case, firms could theoretically write a long-term contract with the inventor. However, one can consider that the lifetime inventions generated by the inventor could be captured (using a net-present discounted value) using a suitable V.

Lastly, the internal stream of innovations C^H has an impact upon the model. Whereas in the model with a single inventor the internal innovation stream did not affect bargaining (as the profits from the internal stream only realize profits in the *next* period), in the framework with infinite inventors, this stream has an impact. Introducing the benefit to remaining the leader satisfies intuition, as well as controlling, to a certain extent, for the strategy whereby a laggard firm actively seeks to maintain its laggard status to gain access to a profitable stream of incremental external innovations.

Finally we add a discount factor, expressed as $\beta \in (0, 1)$. The discount rate factors once per period - for example, if two periods pass profits are discounted by a factor of β^2.

Full Property Rights

In the infinite-period case, in any given period, ex-ante to the value of the invention being realized, the game is equivalent to any other period. There is a leader and a laggard, given probability of inventions of a certain type appearing, and infinite periods remaining in the future.

Proposition 3 In an infinite-period bargaining framework, I_t, period t's inventor with an innovation of value V_t will engage in simultaneous bargaining and accept the leader's offered contract of $E_V^L + \varepsilon$ if the innovation is incremental, and $E_V^L + \beta(H - L) + \varepsilon$ if the innovation is disruptive, where H as the net present value of all expected profits (after payments to inventors) over infinite periods for the current leader, and L as the net present value of all expected profits for the current laggard.

Proof. Assume $H > L$.

The Nash equilibrium is as follows. For I_t the game is a single-period game, as he does not reappear in the market after selling his first invention. Consequently, after the inventor privately realizes the value of his innovation, he engages in simultaneous bargaining, reflecting the one-period scenario above.

If the innovation is incremental, then the logic is the same as in the one-period case. This is because incremental inventions cannot affect firm characteristics - which means there is no potential future advantages to capturing the current-period innovation. All bargaining is limited to payoffs directly arising from the commercialization of the innovation in the single-period. Thus, the leader will offer $E_S^L + \varepsilon$ to the innovator and solely commercialize the invention.

However, if the innovation is disruptive, then contrary to the one-period case the laggard can potentially offer higher payoffs from the discounted future payoffs by becoming the leader in the next period. The laggard would thus be willing to offer as high as $E_B^L + \beta(H - L)$ - that is, the full value of the additional benefits that the firm would receive by commercializing the disruptive innovation and becoming the leader. This is derived as follows: if the current laggard solely commercializes the invention, then it receives $E_B^L + \beta H$. If it chooses not to commercialize the invention, it remains the laggard and receives βL. The excess is thus $E_B^L + \beta(H - L)$.

It also is important to note the internal innovations if the current period - that is C^H and C^L - would not impact the bargaining dynamics. This is because of two reasons: first, the inventor does not have the ability to alter current-period payoffs of the internal innovation stream, and second, the alteration in the firm's capabilities occurs at the end of the current period. Thus, as the laggard would not become a leader until the next period, the current period payoffs from internal innovations is C^L, i.e. 0. In sum, the payoffs from current-period internal innovations are not affected by the sale of the invention, and thus does not enter into the bargaining.

Despite the additional value that the laggard can offer the inventor due to the excess potential payoffs it receives from becoming the leader in the next period, the current-period leader can always exceed the laggard's offer, as $E_B^H + \beta(H-L) > E_B^L+\beta(H-L)$. Consequently, the leader will offer $E_B^L+\beta(H-L)+\varepsilon$ and win the innovation.

The leader will thus win the innovation in all periods. Consequently, L, the discounted payoffs across all periods for the laggard, is 0. H can be calculated using the following identity: H is equivalent to the expected value of payoffs from current period added to the discounted payoffs from the future, i.e. βH.

In other words, $H = p_B[E_B^H - (E_B^L + \beta(H - L))] + p_S[E_S^H - E_S^L] + C^H + \beta H$.

Given that $p_B + p_S = 1$, and $L = 0$, we can calculate $H = \frac{1}{1-(1-p_B)\beta}[p_B(E_B^H - E_B^L) + p_S(E_S^H - E_S^L) + C^H]$. Thus, $H > L$. ■

The leader thus gains all innovations.

Intuitively, as there is greater value to be gained in the disruptive innovation case from becoming the leader, the leader is forced to pay a higher amount to the disruptive innovator to out-compete the laggard. Consequently, disruptive innovators gain higher payoffs from their invention, as would be expected - however, the increase in payoffs exceeds even the extent to which disruptive technology monopoly profits exceed incremental monopoly profits - the disruptive technology also offers the potential for leadership, which offers significant value in its own right.

No Property Rights

Proposition 4 In an infinite-period bargaining framework (whereby an infinite stream of discrete inventors approach with unique inventions - each invention is viewed as a separate period), I_t, period t's innovator with an innovation of value V_t will engage in sequential bargaining and accept the laggard's offered contract of $(N_S^H + \varepsilon, 0)$ in cases of exclusive and non-exclusive markets, respectively, if the innovation is incremental. If the innovation is a major one, the innovator will accept the laggard's offered contract of $(N_B^H + \beta(H - L) + \varepsilon, 0)$ in the cases of exclusive and non-exclusive markets, respectively

Proof. Once again, the game in any single period, ex-ante to the revelation of the invention value, is equivalent to the game in any other period. There will always be infinite periods remaining, one firm will have the competitive advantage, and the value of the invention will be drawn from the same binomial distribution of incremental and disruptive innovations.

In all cases, the inventor will pursue a sequential bargaining structure as, if the innovation is revealed to both firms, neither has an incentive to compensate the inventor. This is because there is no further agency or bargaining power available to the inventor if complete relevation has occured, as he can no longer influence the effective payoffs of the firms.

Again, we define H as the net present value of all discounted expected payoffs (after payments to inventors) across infinite periods for the current leader, and L as the net present value of all discounted expected payoffs across infinite periods for the current laggard.

We take any given period t. If the invention is incremental, then neither the laggard nor the leader will change its market position if the firm commercializes the intellectual property. The game is then equivalent to the one-period case, as neither firm is incentivized to offer more than the direct monopoly or duopoly profits arising from executing the technology. That is, as the technology does not influence firm characteristics and thus future payoffs, bargaining will be limited to competing around direct market rents. The laggard will thus offer $(N_S^H + \varepsilon, 0)$ to the period t inventor in the exclusive and non-exclusive cases respectively, similar to the one-period no-property rights case analyzed above.

However, if the invention is a major and not an incremental innovation, the game becomes more complex.

As with the single-period case, the inventor will again engage in sequential bargaining, as general diffusion of the innovation eliminates all bargaining power on the side of the inventor. Assuming payoffs are greater than zero, the first firm approached will pay the potential duopoly profits of the other firm to prevent deviation. We will examine two cases: $L > H$ and $H > L$.

Case A: H>L.

If the inventor approaches the leader, the leader would be willing to compensate the innovator if and only if $E_B^H + \beta H - P > N_B^H + \beta H$, where P is the payment to the innovator: Again, $E_B^H + \beta(H - L) - P$ represents the excess payoffs to the firm of not purchasing and commercializing the innovation - this is compared to non-exclusive profits where both firms commercialize.

The laggard would be willing to offer $N_B^L + \beta(H - L)$ to encourage deviation, meaning the leader will have to compensate the inventor $N_B^L + \beta(H - L) + \varepsilon$ to discourage deviation and sale of the invention to the laggard firm. While

$E_B^H + \beta(H - L) - P = E_B^H -\ N_B^L - \varepsilon$ is indeed greater than N_B^H, due to the assumption that exclusive-market profits exceed combine non-exclusive market profits - the inventor would actually find it more profitable to approach the laggard and receive $N_B^H + \beta(H - L)$ from the laggard, instead of $N_B^L + \beta(H - L)$ from the leader

Then, the laggard receives the external innovations whether they are incremental or disruptive, competing as a monopolist for the period. We then calculate $H = p_B[\ C^H + \beta L] + p_S[C^H + \beta H]$ - that is, in both cases the leader receives the benefit from the internal innovation stream, becoming the laggard when the external innovation is a major one and remaining the leader if the external innovation is incremental. We can then calculate $H = \frac{1}{1-p_S\beta}[C^H + p_B\beta L]$. Then $H > L$ if and only if $\frac{1}{1-\beta}C^H > L$.

Similarly, L can be calculated as follows: $L = p_B[E_B^L - (N_B^H + \beta(H - L)) + \beta H] + p_S[E_S^L - N_S^H + \beta L]$. Given that $p_B +\ p_S = 1$, we can simplify the expression to deduce:

$L = \frac{1}{1-\beta}[p_B(E_B^L - N_B^H) + p_S(E_S^L - N_S^H)]$. Consequently, $H > L$ if and only if $C^H > p_B(E_B^L - N_B^H) + p_S(E_S^L - N_S^H)$. Intuitively, if the single-period payoff for the leader's internal innovation exceeds the payoff for the laggard"s innovation with the expected value of the one-period "payoff value" of the innovation, then the equilibrium holds. That is, the internal innovation stream is sufficiently high to support the long-term benefit of being a leader over the laggard.

Case B: L>H

This case increases greatly in complexity. We analyze two sub-cases: if the inventor approaches the laggard first, or if the inventor approaches the leader first.

Case 1: If the inventor first approaches the leader, the leader would commercialize if and only if $E_B^H + \beta(H-L) - P > 0$, that is, if the potential extra benefits from commercializing the technology exceeds the price paid. Seeing the disclosure of the innovation to the leader, the laggard would offer its full additional profits from receiving the major innovation to encourage deviation - namely, $N_B^L + \beta(H-L)$. However, as we have assumed $H < L$, $\beta(H-L) < 0$, there is the possibility that $N_B^L + \beta(H-L) < 0$ - in which case the laggard would not be willing to pay the inventor to deviate as it would result in a net decrease in payoffs. Given that deviation is not a credible threat, the leader will then only pay a minimal amount to the inventor - just enough to persuade it to sell the invention - and receive the innovation, remaining the leader. However, if $N_B^H + \beta(H-L) > 0$, then the inventor will be compensated if it approaches the laggard firm. Consequently, this equilibrium holds if and only if $N_B^H + \beta(H-L) < 0$.

However, if $N_B^L + \beta(H-L) > 0$, then the leader will pay $N_B^L + \beta(H-L)$ to the inventor to prevent deviation. In this case, $N_B^H + \beta(H-L) > N_B^L + \beta(H-L)$ > 0 - that is, the leader would be willing to pay more for deviation than the laggard in the same scenario. Thus, if $N_B^L + \beta(H - L) > 0$ - that is, if the laggard finds it valuable to commercialize the technology in a duopoly scenario - the inventor would approach the laggard instead.

Consequently, the assumptions of Case 1 (i.e. that the rational inventor would approach the leader) hold if and only if $N_B^H + \beta(H - L) < 0$, in which case the innovator will only be compensated a minimal amount.

In other words, if the inventor approaches the leader it will either make minimal profit or find it more profitable to approach the laggard instead. Knowing this, the rational inventor would either be indifferent or find it more valuable to approach the laggard, so long as the laggard finds it worthwhile to comercialize the technology - that is, if $N_B^L + \beta(H - L) > 0$. In other words, approaching the leader is weakly dominated by approaching the laggard - so we may consider only the case of approaching the laggard except when $E_B^L < \beta(L - H)$. In this case, the laggard will always remain the laggard, and the leader always remain the leader - the leader will receive all disruptive innovations and the laggard all incremental innovations

Then, $H = p_B[C^H + E_B^H + \beta H] + p_S[C^H + \beta H]$, and

$L = p_B[\beta L] + p_S[E_S^H - N_S^H + \beta L]$. We can simplify these expressions to find $H = \frac{1}{1-\beta}[C^H + p_B E_B^H]$, and $L = \frac{1}{1-\beta}[p_S(E_S^L - N_S^H)]$. Then $H < L$ if and only if $C^H + p_B E_B^H < p_S(E_S^L - N_S^H)$. However, as $C^H > 0$ and $E_B^H > E_S^L > E_S^L - N_S^H$, the inequality holds only under fairly extreme conditions for p_B. We must have

$p_B < \frac{E_S^L - N_S^H - C^H}{E_B^H + E_S^L - N_S^H}$, and $E_B^L < \frac{\beta}{1-\beta}[p_S(E_S^L - N_S^H) - p_B E_B^L - C^H]$ simultaneously. The second inequality holds only if $1 < \beta(1 + p_B)$, as otherwise we would have $\frac{1-\beta}{1-\beta(1+p_S)} E_B^L$ less than a negative value. If the inequality holds, we can simplify to $E_B^L > \frac{\beta(1-\beta)}{\beta(1+p_S)-1}[p_S N_S^H + p_B E_B^H + C^B]$, which is a decreasing function of $p_B = 1 - p_S$.

Therefore, this condition holds under rather extreme conditions - that is, if p_B is very low.

Case 2: If the inventor first approaches the laggard firm, the current leader would offer its full additional profits from receiving the disruptive innovation than it would receive if it does not receive the innovation (becoming the laggard in future periods). Further, the laggard would only execute the innovation if the value it receives from commercializing exceeds the value it receives from "deferring" and remaining the laggard. This would only happen if $E_B^L + \beta(H - L) - P > 0$. However, as we have assumed $\beta(H - L) < 0$, there is the possibility that $E_B^L + \beta(H - L) - P < 0$, i.e. the payoffs from commercializing the disruptive innovation this period is actually less than the discounted payoffs by "deferring" and becoming the laggard in the following period, which

Case 2.a) Assume that the laggard would not commercialize - that is, $E_B^L + \beta(H - L) - P < 0$. Then, the inventor would not receive any payoffs from the laggard, and would receive no payoffs at all as neither firm would be willing to compensate the inventor after the initial disclosure - the inventor then has no ability to threaten defection and diffusion of the technology. Knowing this, a rational inventor would instead approach the leader first, contradicting the assumption of Case 2. We thus move on to the case where the laggard would commercialize.

Case 2.b) Now, we examine the case where the laggard would actually commercialize - that is, if $E_B^L + \beta(H - L) - P > 0$. Then, mathematically, the leader would offer $P = max(N_B^H + \beta(H - L), 0)$ to the inventor to try and encourage deviation.

Then, if $N_B^H < \beta(L - H)$, the firm would not be willing to offer anything to deviate - it would rather defer the invention, and wait to become the laggard in the next period. The inventor would then not be paid by the leader for deviation, as there would be no value to commercializing the inventiton in the duopoly state. Then, the laggard will only compensate the inventor a minimal amount to persuade it to sell the invention.

On the other hand, if $N_B^H > \beta(L-H)$, the leader will offer $N_B^H + \beta(H-L)$ to incentivize deviation. Then, the laggard will pay $N_B^H + \beta(H - L) + \varepsilon$. Given that $N_B^H + \beta(H - L) + \varepsilon > N_B^L + \beta(H - L) + \varepsilon$, the inventor will approach the laggard, similar to the single-period case. In this case, the laggard will receive the invention in all periods, and we can calculate H and L.

The calculation is now identical to the Case A scenario. Thus, $H = p_B[$

$C^H + \beta L] + p_S[C^H + \beta H]$, and $L = p_B[E_B^L - (N_B^H + \beta(H - L)) + \beta H] + p_S[E_S^L - N_S^H + \beta L]$, and $H < L$ if and only if $C^H < p_B(E_B^L - N_B^H) + p_S(E_S^L - E_S^H)$.

Evaluating all the subcases, we thus conclude that the laggard receives all innovations if $C^H > p_B(E_B^L - N_B^H) + p_S(E_S^L - N_S^H)$. Otherwise, the inventor would only earn minimal returns unless $N_B^H > \beta(L - H)$, where $L - H = \frac{1}{1-\beta}[p_B(E_B^L - N_B^H) + p_S(E_S^L - N_S^H)] - \frac{1}{1-p_S\beta}[C^H + p_B\beta L]$ ■

In intuitive terms the basic logic of the above proof is similar to the single-period case for no-property rights scenarios. However, a new tension arises from the following. Although leaders generate more valuable internal innovations and generate higher payoffs when absorbing external innovation, laggards win both major and incremental innovations in Nash equilibrium (because approaching the laggards is a weakly dominant strategy for the inventor). Consequently, firms face a tradeoff between the stream of incremental innovations and the chance to win a major innovation versus the stream of internal innovations that firms can earn by becoming the leader. Depending on the distribution of the values of commercializing external and internal technologies, the inventor may earn only minimal returns to his technology. In one extreme case, if the payoffs from commercializing the major technology for the laggard is very low, then the laggard would actually find it preferable to "defer" commercializing the disruptive technology in favor of remaining the laggard. However, again this relies upon very low monopoly payoffs from commercializing a disruptive technology - a somewhat unrealistic assumption.

The scenarios where payoffs to the inventors are non-trivial take two primary forms: either the value of the internal technology stream of the leaders is sufficiently high to ensure sale of disruptive inventions, or the leader earns enough profits in hypothetical duopoly scenarios to consider purchasing deviation if the innovator approaches the laggard. In other words, disruptive innovators are paid when being the leader is "valuable enough" to pre-empt deferral or make deviation an empty threat. There is one scenario where innovators would approach the leader in the no-property rights scenario - that is, when the current innovation is disruptive and the probability of future disruptive innovations is extremely low. However, the equilibrium finds that even when disruptive inventors would not capture a high level of rents from their innovations, they would still sell their ideas to the laggard in all periods, except for the extreme case mentioned above.

1.3 Discussion

The above model includes some assumptions that may be extended or altered in future research. We discuss how the results may not fully reflect the reality of innovation markets, how the model may be extended in future research, and how the results may otherwise be subjected to tests to develop an intuition for the robustness of the results.

First, we have currently assumed only two potential buyers of intellectual property in the market. This is not necessarily an accurate reflection of reality, as firms are always entering and leaving technological areas, and inventors may have access to a higher number of sellers. However, extending to a higher number of buyers will not necessarily alter the results or reasoning. In the complete property rights case, the inventor can still employ an open bargaining framework and sell his invention to the firm that can afford to outbid all other competitors - which would be the "leader" as characterized by its ability to commercialize intellectual property rights. In the no-property rights scenario, the inventor will again threaten diffusion to bargain with the potential seller. To maximize returns, the inventor would approach a firm that would pay greater amounts to prevent deviation. This would not be the leading firm - the leading firm would pay the highest amount to encourage deviation, so rival firms would be forced to pay greater amounts to prevent this. An interesting wrinkle arises if non-duopoly (i.e. oligopolistic) profits exceed duopolist-scenario payoffs, allowing inventors to diffuse the innovation across multiple potential buyers. However, this is a relatively unrealistic scenario, as total economic rents are destroyed as more competitors enter the market and push the market to perfect competition. Lower numbers of buyers is also not necessarily highly unrealistic from the inventor's perspective, as search and exposure costs for inventors looking to their commercialization invention can be significant, causing inventors to be aware of only a small number of potential buyers.

Another interesting potential extension arises from incorporating "weak" property rights instead of examining only full or no property rights. Weak property rights could potentailly be examined by modeling rights-holders as being able to capture a certain fraction of rents generated by the commercializer when expropriation occurs - we can then develop a spectrum of property rights regimes. However, in the equilibria defined above, expropriation does not actually occur. The existence of limited property rights essentially guarantees a minimum level of return to the innovator - if the proportion is sufficiently high the proportion of monopoly rights generated by the expropriator may exceed duopoly profits offered by the firm not approached. In this case, expropriation is actually encouraged - or rather, essentially an unofficial contract occurs where the monopolist compensates the inventor. Then, this is essentially similar to the full property rights case.

There are alternative methods to reflect weak property rights or the nature of innovation that more fundamentally alter the dynamics. For instance, the model could incorporate a litigation sub-game, where if expropriation occurs innovators could pay a certain cost to a legal counsel in return for a probability of compensation. The model may also be extended to include reputational effects, where firms that repeatedly expropriate become known for this behavior. As mentioned above, the equilibrium does not actually include expropriation. However, the reputation structure would result in costs to the firm from expropriating behavior.

We may also include partial disclosure of innovation akin to Anton and Yao (2008), whereby the inventor can target a certain level of intended disclosure, but with a certain probability risk complete disclosure. If the invention is fully revealed, the situation is identical to the full property rights scenario - the leader will out-offer the laggard, who will offer his full rents from gaining access to the innovation. However, in order to avoid deviation from the inventor after the innovation has been fully revealed to the leader, the leader will have to offer an ex-poste contract where compensation is paid after market structure has been realized. If full disclosure is avoided, however, the inventor may be able to target a level of disclosure whereby value is telegraphed but not fully disclosed, resulting in a scenario similar to the full-property rights case.

Currently, the model considers internal innovations as entirely separate from external technologies. However, the model may have scenarios where the same innovation is developed by the firm as with the external firm. If both firms have self-invented, then the innovator would not be able to realize any profits. however, if one firm already has the invention, the innovator would only be able to earn income from threatening diffusion to the firm that does not currently possess the innovation. In full property rights cases, the current invention-holder would pay the duopoly profits that the competitor would earn if it also gained access - identical to the bargaining in the low property-rights case. Depending on which firm has self-innovated, the innovator could approach the leader or the laggard. Intuitively the leader would be more likely to self-innovate - consequently, becoming the leader is more attractive even in no-property rights scenarios, and "deferral" strategies, as discussed above, would be less likely to occur on the part of the laggard. Finally, an interesting extension could incorporate strategic choice in internal R&D investment, in other words where firms can increase spending to either increase the internal innovation value or potentially increase the rate of self-innovating. In this case, we may find that in weak property rights scenarios, current leader firms would find it more valuable to invest internally in R&D over purchasing external innovations.

Finally, as discussed briefly above, if innovators enter the marketplace repeatedly and are not limited to only one innovation, then firms can develop long-term contracts around them. In this case, the innovator is essentially brought in-house, contributing to the internal stream of innovation. After time, the innovator would develop a reputation for quality, reducing the need for disclosure to verify the value of the invention, moving the bargaining closer to a full property rights scenario.

1.4 Conclusion

In this essay, we develop a game-theoretic model for the sale of intellectual property rights from small, independent inventors to firms in strong and weak property rights. We consider this scenario with the addition of dynamically heterogeneous firms, where technical and commercialization ability, encompassing its technological absorptive capacity, change depending on whether certain technologies are incorporated and commercialized. We find that, given certain conditions, in both the single and infinite-period cases, the inventor would sell his innovation to the leader if property rights offer full protection, and to the laggard if property rights do not offer any protection. The infinite-period result holds when either the internal innovation stream is sufficiently valuable for leaders, or if the probability of disruptive innovations is very low.

We considered possible future research, although intuitively the result is fairly robust against various extensions, such as including multiple potential buyers and considering "weak" instead of no property rights. The results thus suggest divergent equilibria across different property rights scenarios, and has implications for how innovators may approach the sale of their intellectual property depending on firm characteristics and variable property rights.

Chapter 2
Selling to the Leader or the Laggard? Exploring the Impact of Property Rights Upon Innovator Patent Sales

2.1 Introduction

The market for innovation, i.e. the buying, licensing and sale of patents, is a critical value-driver for firms and inventors, whether it allows firms to acquire patents to gain access to commercializable technology and protect their existing innovations, or whether it facilitates commercialization of existing stock of patents via selling or licensing. Particularly since the mid-1980s, the United States has seen a dramatic surge in patent activity, from filing to transfer to licensing. Stories of multi-million, sometimes multi-billion dollar purchases of patent portfolios routinely cross headlines.But the dynamics of patent sales faces many frictions and transactions costs. As such, it is difficult to predict the impact of changing property rights upon the movement of patents and innovation.

The literature suggests many reasons firms acquire patents, and often examines the issue as a decision in context of the firm's strategy as to whether to acquire a patent or not (Somaya (2012), Duysters and Hagedoorn (2000), Anton and Yao (2004)). However, the decision of the seller facing a heterogeneous marketplace of buyers has been relatively less examined - particularly in a dynamically changing environment. In this paper, I explore the following question: how do small innovators or sellers of patents alter their strategies in environments with weakening property rights?

To capture such changes in the environment, I exploit that patents are inherently legal documents. Depending upon the strength or weakness of the appropriability regime - that is, the legal environmental factors determining the ease of infringement or imitation of a commercializable intellectual property - optimal firm and inventor strategies for the sale, acquisition, and implementation of patents can change significantly. In particular, I use *Markman v. Westview Instruments, Inc.,* 517 U.S. 370 (1996) - a landmark Supreme Court case whereby courts, especially the Court of Appeals, Federal Circuit (or CAFC, established in 1982), were given a higher level of jurisidiction over a given patent's claims, i.e. the scope of protection offered by the patent. This had the effect of weakening property rights for several reasons, including the granting of greater oversight to judges over juries, who tended to be more inventor-friendly (juries ruled for patent-holders 68 percent of the time, opposed to judge's 51 percent (Moore (2000))).

Using a dataset of patent trades from 1992 to 2000 gathered by the USPTO, I examine the impact of *Markman v. Westview Instruments* upon patent trading patterns, particularly from small-scale or individual inventors to larger firms. I use a conditional fixed-effects multivariate choice regression to determine the impact of a potential patent buyer's commercialization capabilities, measured as patent holdings in a given time frame and the same industry, as defined by the as the patent being traded.

The primary result is that after *Markman v. Westview Instruments* - that is, after patent strength was weakened - inventors and small entities are more likely to sell patents to firms with lower commercialization capabilities. This result has implications for both sellers and buyers of patents, in terms of maximizing the payoff from external payoffs for their inventions, and optimizing strategy to acquire external innovations instead of conducting internal R&D dpeending on the strength of property rights, respectively. The redistribution of value-generating innovations is also important for policy makers, as they may find that - contrary to intuition, strong property rights results in the concentration of property rights over time.

The article is organized as follows. Section 2 motivates the research question and explores relevant literature. Section 3 explains the data, presenting stylized facts. Section 4 discusses the methodology for empirical estimation. Section 5 presents the estimation results, in particular the impact of Markman v. Westview Instruments upon the pattern of sales activity from inventors to large firms, and discusses potential explanation. Section 6 concludes.

2.2 Motivation

This paper sits at the juncture of two strands of thought: one from management science, regarding the market for intellectual property (IP) and its interaction with appropriability regimes, and the other from the legal literature regarding patent court rulings, particularly the impact of Markman v. Westview Instruments.

2.2.1 The Market for Patents

Academics have examined multiple reasons that firms acquire patents. Companies may desire the proprietary value of the patent, i.e. the direct technological value of the innovation underlying the patent (Somaya (2012)), to expand their existing technological capabilities or to develop and commercialize new technologies (Duysters and Hagedoorn (2000)). Firms may also acquire patents for their defensive value, or the patent's ability to prevent erosion of rents from holdup or litigation by outside entities holding patents that may prevent commercialization. Finally, firms may wish to acquire patents for their licensing revenue or for indirect benefits, such as access to cross-licenses or nonmarket strategic value from competitors developing products based upon the same underlying technologies (Arora, Fosfuri (2003)).

On the other hand there are significant costs and frictions that arise from technology transfer, both in terms of direct transfer costs (Teece (1977)) and transactions costs arising from appropriation, expropriation, and hold-up (Teece (1986), Williamson (1991), Anton and Yao (1994), Shapiro (2001)). These problems are exacerbated in weak property rights regimes. While patents provide a potential legal mechanism where innovators may protect their invention, patents are imperfect defensive instruments as they can be fuzzy or imprecise, (Linden & Somaya (2003), Teece, (2000)), "invented around," (Mansfield, Schwartz, and Wagner (1981)), and expensive to litigate if expropriated (assuming infringement is detected at all) (Encaoua and Lefouili (2005), Shane and Somaya (2007)).

In response, firms have developed a variety of countermeasures. In industries with weaker property regimes, firms often construct patent portfolios or "thickets," using overlapping claims to bolster the defense of a critical technology. Or, they may cooperate with other firms to build patent pools, where each member contributes patents from which all other members can draw, or alternatively cross-license across a broad variety of patents and firms (Shapiro (2001)). Ziedonis (2004) finds that fragmented property rights (i.e. when ownership rights for related, sequential innovations are spread across multiple owners) incentivize firms to acquire patents aggressively in order to pre-empt holdup or litigation in the future.

On the selling side of the technology market, a particularly valuable source of external innovation for firms is inventors or small, technologically proficient companies such as start-ups (Gans, Stern (2003)). Arora, Fosfuri, and Gambardella (2001) and Gans, Stern (2003) note that effcient markets for innovation allows smaller firms to specialize in innovation and development because access to such markets gives small innovators the ability to earn returns without investing in commercialization methods. But small innovators face unique challenges when selling their ideas. A major dilemma is the *paradox of disclosure* (Arrow (1962), Anton and Yao (1994)). While small innovators must typically disclose their ideas in order to credibly signal the value of their invention, this also renders them liable to expropriation by the very same potential buyers. Scholars have suggested several theoretical mechanisms by which these small innovators may capture value from their inventions despite this paradox. Anton and Yao (1994) suggest that innovators may earn compensation by threatening diffusion of the invention to competitors, by only partially disclosing their invention (Anton and Yao (2002)), or by patenting (as opposed to relying on trade secrets) "small", less valuable innovations (Anton and Yao (2004)), although Serrano (2010) finds that more valuable patents with higher citation counts are more likely to be traded. Teece (1986) suggests that in weak approriability regimes, innovators should invest in complementary assets.

An expanding area of literature explores the type of buyers who innovators should approach. Depending on the characteristics of the buyer, innovators may run higher risks of expropriation or earn substantially greater rents. Ahn and Yao (2015) suggests that innovators should choose firms with lower commercialization capabilities, i.e. the ability to realize the value of a given IP (whether through defensive, proprietary, or licensing capacities), when IP regimes weaken. However, this stream remains primarily theoretical.

Our contribution lies in empirically exploring the question of how small innovators respond to weak property rights regimes by comparing their choice of buyers across different appropriability environments. By examining in‡uence upon buyer choice, our results may suggest prescriptive advice for innovators on how to select the potential buyer and provide context for firms in their patent acquisition activities. Given the predictions of Ahn and Yao (2015), we examine buyer choice as it is determined by a firm's commercialization and defensive capability.

We exploit a relatively novel dataset on patent transfers, based on USPTO recording of patent reassignments, which are required whenever transfers occur (otherwise the transfer may not be binding). The empirical literature on small innovator behavior has mainly focused upon licensing agreements aside from from Serrano (2005, 2010), for instance finding that successful startups in biotechnology industry have generally entered licensing agreements or alliances (Stern (1995), Lerner and Merges (1998)). However, patent transfers have unique properties. While licensing grants access to the underlying technology, usually at the cost of some royalties, it does not grant ownership privileges unless otherwise specified. This includes using patents to prevent imitation, rent-seeking through sub-licenses, settlement decisions, etc. Further, the licensee bears the risk that the licensor may terminate the contract and holdup the licensee's rents, or that the licensor may license the same technology to competitors. Galasso, Schankerman, and Serrano (2013) show that transfer of patents reduce the likelihood of litigation on average. Patent transfers, therefore, potentially captures the movement of particularly valuable IP.

The Patent Legal Environment

As patents are legal instruments, patent court rulings play a powerful role in the strength of the patent regime in our dataset. Since the 1980s, the United States has undergone substantial shifts in its patent environment. Prior to the establishment of the CAFC, district courts had managed the majority of patent infringement rulings, encouraging a certain amount of "forum shopping" where litigators approached courts known to be more supportive of patentees or infringers, depending on need (Jaffe (2000), Gallini (2002)). The CAFC consolidated patent activity into a new federal appeals court, introducing a centralized environment for patent litigation on appeals before the involvement of the Supreme Court. It is generally understood that the CAFC was pro-patent, i.e. that it typically ruled in favor of patentees instead of infringers. (Allison and Lemley (1998), Jaffe (2000), and Gallini (2002)). The CAFC upheld the validity of patents at a higher rate than prior to its establishment. Further, as the CAFC represented a new specialized court in the appeals process, providing jurisdiction over patent-specific federal cases before the involvement of the Supreme Court, the CAFC had a particularly strong influence on the legal landscape of patents.

But in the mid-1990s the patent environment once again began to shift as the Supreme Court began to issue rulings that sharply curtailed the scope of upheld patents (Lunney (2004)). Rulings reducing the scope of patents made it easier for infringers to defend themselves in court, as they could argue they did not cover more limited claims of a given patent. *Markman v. Westview Instruments* represents a watershed moment in patent law where patents were significantly challenged in scope. Herbert Markman, an inventor, brought an infringement suit against Westview Instruments, Inc., claiming that the latter expropriated his invention of an inventory system for dry cleaning. Over the process of appeals, the case evolved into a debate regarding the jurisidiction of patent claim construction, i.e. the scope and exact claims which a patent could protect. Finally, in a unanimous decision, the Supreme Court ruled that it was the jurisdiction of the judge and the court (and ultimately the appellate and federal courts), not the jury, to determine the claim construction for patents.[12] During a discussion with the author on pivotal patent rulings in the past twenty years, a practicing attorney in intellectual property law noted that *Markman v. Westview* Instruments was "probably the most important patent law case in the last few decades...resulting in 'Markman hearings' in every patent case since then, essentially miniature trials before the judge to determine what exactly the patent language means." In the legal community, Markman hearings are often described as the most significant part of patent litigation, as claim construction is an essential aspect of almost any patent case.[13]

From the perspective of appropriability regimes, *Markman v. Westview Instruments* had a negative impact on the strength of property rights. This is due to a variety of factors. The primary cause was the significant increase in the cost of litigating infringers, which derived from the new requirement of Markman hearings. Professor Edmund Sease of Drake University Law School (a practicing attorney and partner at his law firm) writes (Sease 2004):

> "Patent litigation has become notoriously expensive... Garden-variety patent case incur[s] attorneys' fees of at least one million dollars. A case of any substance or size normally has larger fees, typically within the range of one to two million dollars. These ever escalating costs are... a result of requiring a separate *Markman hearing* (italics added for emphasis) ... [Patentees] must prevail twice [due to Markman hearings] before they ever have a chance for a judgment!"

In addition, *Markman v. Westview* reduced the likelihood of plaintiff (patentee) victory in trial. It is well-documented that juries are pro-patent, more so than judges, possibly due to the fact that juries are enamored of the inventor's journey narrative (Moore (2000)). Consequently, the shift of the power of patent rulings post-Markman towards the court and judges had a significantly negative impact upon the rate of rulings in favor of patentees. In her study on judge vs. jury rulings on patent infringement cases, Moore (2000) explores a dataset of patent rulings from the Administrative Office of the United States Courts from 1983 to 1999, and finds that juries rule in favor of the patentee 68 percent of the time, as opposed to the judge's 51 percent, corroborating Allison and Lemley (1998). Jaffe (2000) finds that in 1990, district court rulings on patent validity and infringement were upheld on appeal 90% of the time (rising from 62% in 1980; patent invalidity claims were overturned 28% of the time in 1990, rising from 12% in 1980. Altogether, litigated patent validity had risen to 54% by 1990). On the other hand, Moore (2005) finds that post-Markman, the central appeals court CAFC ruled in favor of the *infringer* 58 percent of the time. Altogether, the statistics suggest that after Markman patent holders faced an IP regime with a substantially higher risk of facing infringement and appropriation without legal protection.

Given the significance and effect of the *Markman v. Westview* ruling, we examine how patent buyer choice (based on commercialization and defensive capabilities) for innovators changed from before to after the ruling. The results may give insight as to how innovators respond to legal shifts in property rights environments.

2.3 Data Review

We use the most recent version of the dataset of patent filings and citations drawn from the NBER patent database assembled by Jaffe, Trajtenberg, and Henderson from the USPTO, described in Jaffe, Trajtenberg, and Henderson (2001) but updated through 2006. We examine transfers from individuals, non-corporate entities excluding universities and government, and undeffned entities (according to the HJT entity classiffcation category) to U.S. corporations. The data consists of 13,619 patent transfers from individuals and small firms to U.S. corporations from 1992 to 2000 of patents classified as HJT technological category 2, consisting of communications, computer hardware & software, computer peripherals, and information storage patents. We examine a single general industry to limit the variations that arise from different business practices across different industry classifications (and accordant industries). This set corresponds to 94 technological categories in the International Patent Classification (IPC) system. Individuals were determined by the entity classification performed by Hall, Jaffe, and Trajtenberg (2001), which separated assignees as U.S. and non-U.S. nongovernmental organizations, U.S. or foreign individuals, U.S. or foreign governments, or U.S. non-Federal government agency. In the period before *Markman v. Westview*, the traded patents spanned 62 industries, while in the period after *Markman v. Westview* the patents spanned 85 industries. 53 industries were common across both periods. Small firms were determined as those that were issued less than five total patents in a given year, paralleling Serrano (2005).[4]

To the extent possible, we removed all acquirers that are non-practicing entities (NPEs) or "trolls", i.e. entities that acquire patents with no intent of commercializing patents but rather solely to litigate and extract licensing fees from other firms. As NPEs are not involved in the value chain (aside from potentially providing liquidity and matching services for technology), acquisitions by NPEs are not associated with the strategic aspects of innovation markets as described above, and may potentially confuse results. We remove NPEs from our transfer data by matching entity names with a list of known NPEs, provided by www.patentfreedom.com, which lists over 830 NPEs as of July 2014.

Employer-employee relationships were also controlled for by examining the date of transfer and the date of grant. If the transfer of the patent occured within 3 months of the patent's grant, it was deemed to be an employer-employee relationship. Further, if an inventor sells multiple times to the same firm, this suggests to a certain extent that a relationship has developed between the buyer and the seller. As this could influence the dynamics of the patent sale decision, we removed all repeat sales from the dataset as well. While this loses some of the dynamics of sellers changing their buyers due to varying offers, as discussed this introduces potential complexities into the bargaining dynamics that may affect the analysis.

Table 1 provides some descriptive statistics on those firms that purchase patents from innovators.

Table 1: Summary Statistics on Actual Buyers

Variable name	Mean	SD	Median	Min	Max
Public Buyers: 104 Firms					
Annual R&D (thousand $)	2,017.6	1,825.6	1181	0.045	8,387.9
Annual Revenue (thousand $)	30,402.6	30,528.6	13,673	1.54	165,370.2
R&D Int.	0.088	0.205	0.075	0.001	10.7
Emp. Count (hundreds)	109.3	111.1	48.5	0.014	750
Capital Intensity	83.2	68.4	68.4	6.6	887.8
Tot. Holdings	370.1	464	98	1	1,783
Private Buyers: 222 Firms					
Tot. Holdings	7.1	6.5	3	1	40

*age is measured as date of trade minus date of filing

As discussed in the motivation, we wish to study how patent buyer choice is in‡uenced by varying appropriability regimes. In particular, we wish to examine buyer commercialization and defensive capabilities, as suggested by Ahn and Yao (2015). To capture this commercialization and defensive capability for firms, we use a measure of patent holdings. More specifically, we proxy commercialization and defensive capability by using total patent holdings held by a firm in the same technological classification as the patent being traded, normalized by the median of the firms with an active presence in that technological category. A large and diverse patent portfolio signals the firm's ability to commercialize a wide array of technology, or prevent other firms from doing the same, and to potentially defend itself through counter-litigation. Further, as patents can be costly to acquire and maintain, they can signal other information about the firm's capabilities. Patent counts thus serve as a credible signal of firm quality and value (Parchomovsky and Wagner (2005)). We normalize this measure by dividing the patent count with the median of the holdings of the active firms within the technological classification. This controls for industries with high patent counts in general, and captures the relative strength and capabilities of a firm within a given technological area.[5] It is important to note, however, that patent classifications distinguish on a technological level but not necessarily on an industrial one - firms holding patents in the same category are more likely to indicate use of such technology over pure competition in the same area, as a measure such as SIC code would indicate. However, from the perspective of a patent seller, the potential buyers' differences in competing in different but related industries (for example, at different stages in the workstream) are not as strictly relevant as the size of the buyer and the extent to which they use the given technology. In other words, the commercial capabilities of the buyer can be considered separate from direct competition, and is relevant to the buyer as long as they use similar technologies and are thus potential buyers for the seller's patent.

Among those firms that acquire patents from individual innovators, the average number of trade acquisitions per firm per year is 9.83, with a standard deviation of 40.61. The average number of acquisitions by a given firm over its lifetime is 20.47 trades, with a standard deviation of 148.95. We collect information on firm operating activity, including R&D spending, revenue, employee count, etc. However, this data is only available for public firms. Of the 415 buyers, 282 of them are private, but public buyers are responsible for 11,385 transfers (83.6 percent). This implies that the vast majority of transfers are conducted by public firms. Further, public firms have much higher average holdings, as indicated in Table 2; the average total holdings (per technological classification of trade) is 370, as opposed to 6 for private firms. This may reflect the higher general size and revenue of public firms as opposed to private ones, and thus their higher holding counts.

To provide a baseline for comparison for the actual patent buyers to potential other buyers that the innovator may choose, we organize the data to provide information on potential alternative buyers for the traded patents. We select these alternative buyers as those firms that filed or purchased at least two patents (as the list of firms that acquire only one patent is very high, and not necessarily indicative of significant activity) in the same primary IPC classification of the traded patent within a two-year window of the trade. This indicates that the firm has an active presence in the same technological area during that time.[6] To distinguish between potential buyers and actual buyers in the data, we generate a categorical variable that records 1 if a trade for a patent occurs to a specific buyer in the year of trade and 0 otherwise. This is used as the estimate for the dependent variable in the estimation.

Table 2 lists some summary statistics on potential patent buyers, prior to *Markman v. Westview Instruments*.

Table 2: Summary Statistics on Potential Buyers, Pre-Markman

Variable name	Mean	SD	Median	Min	Max
Public Buyers: 182 Firms					
Annual R&D (th %)	868.2	1,606.6	226	0.045	8,387.9
Annual Revenue (th $)	16,263.0	32,100.5	3,375.3	1.24	165,370.2
R&D Int.	0.103	0.204	0.069	0.001	3.48
Emp. Count (hnd)	76.7	143.9	20.3	0.054	750
Capital Int.	62.2	77.4	45.6	6.2	935.9
Tot. Holdings	22.3	69.0	6	2	968
Private Buyers: 212 Firms					
Tot. Holdings	6.0	7.6	2	1	36

*age is measured as date of trade minus date of filing

Prior to the Markman ruling, there are on average 151 potential (or "alternative") buyers per transferred patent, with a range from 11 to 202 possible buyers (including the actual buyer). There are a total of 394 unique potential buyers prior to Markman. R&D Intensity is actually slightly lower for actual buyers than it is for potential buyers, although in absolute terms both revenue and R&D spending are approximately half what they are for actual buyers. Actual buyers tend to be slightly larger in size compared to the average potential buyer in terms of employee count (109.3 over 76.7). Actual buyers, on average, have significantly higher average patent holdings (per technological category of traded firms) than do potential buyers, at least among public firms, although this is driven in part by a high number of firms that have holdings of only two patents within the technological category.

Table 3: Summary Statistics on Potential Buyers, Post-Markman

Variable name	Mean	SD	Median	Min	Max
Public Potential Buyers: 340 Firms					
Annual R&D (th %)	952.5	1,724.1	220.9	0.0	8,900.0
Annual Revenue (th $)	17,312.0	33,003.9	3,621.2	0.066	206,083
R&D Int.	0.136	0.474	0.077	0.000	10.69
Emp. Count (hnd)	69.4	123.6	13	0.002	647
Capital Int.	70.8	88.1	49.9	2.0	1,112.4
Tot. Holdings	32.7	117.2	6	2	2,249
Private Buyers: 525Firms					
Tot. Holdings	7.6	9.5	3	2	203

* age is measured as date of trade minus date of filing

After the Markman ruling, there are on average 216 potential (or "alternative") buyers per transferred patent, with a range from 4 to 453 possible buyers (including the actual buyer). There are a total of 865 unique potential buyers prior to Markman. The annual revenue, R&D, employee count, and capital and R&D intensity figures seem largely comparable across periods, although the average holdings count is slightly higher for the post-Markman period for public companies. Again, we see that private potential buyers have much lower patent holdings than public firms.

Of the 394 unique potential buyers that appeared before the *Markman v. Westview* rulings, 264 (67%) reappear after the Markman ruling across the same industry, indicating a degree of homogeneity in the market of potential buyers faced by patent sellers. In other words, approximately two-thirds of the buyers available to sellers prior to Markman are still present after Markman. We also examine some characteristics of the patents themselves. Table 4 below summarizes the lifetime forward citation counts and the age of traded patents before and after *Markman v. Westview*.

Table4: Summary Statistics on Traded Patents

Variable name	Mean	SD	Median	Min	Max
Pre-Markman: 6,785 Traded Patents					
Fwd Cites	21.4	25.7	14	0	526
Age	2.59	1.10	3	0	11
Post-Markman:6,834 Traded Patents					
Fwd Cites	16.9	21.6	10	0	329
Age	2.19	1.26	2	0	15
Total Set: 13,619 Traded Patents					
Fwd Cites	19.4	23.8	12	0	526
Age	2.39	1.20	2	0	15

The average number of citations per traded patent in its lifetime is 19.4 citations, with a standard deviation of 23.8. As citations may indicate higher value (Hall, Jaffe, Trajtenberg (2005)), this suggests that most traded patents are at least somewhat valuable, corroborating Serrano (2010); only 2.33 percent of traded patents in the dataset generate no citations in their lifetime. This indicates that reassignment occurs when patents are particularly valuable. As would be expected considering we are examining transfers from individuals to firms, the vast majority of reassignments in the datasets are first-time transfers in the patent's life, suggesting that buyers are able to identify value relatively early in the lifecycle of a patent. This corroborates intuitively with the notion that the value of traded patents is understood by industrial buyers and potentially competed over.

There are 415 unique buyers for the 13,619 transfers. Most buyers are therefore repeat buyers. As discussed earlier, repeated sales between the same buyer and seller has been removed. However, with the dominance of particular buyers in the marketplace, this raises the notion that certain firms can develop reputations in the market, which could incentivize certain sellers to sell their patents to firms with greater reputations. However, with the usage of fixed-effects, such firm-specific year-specific effects can be mitigated or otherwise controlled for.

2.4 Methodology

We divide the dataset into two periods: before the *Markman v. Westview* ruling in 1996, and after. The two time periods are thus 1992-1996, and 1996- 2000. The periods are divided directly before and after by the date the ruling was decided: April 23,1996.[7]

We apply a fixed-effect logistic (logit) model for panel data (Greene (2010)) on both periods. The logit captures the effect of various potential-buyer-specific independent variables upon discrete choice - in this case, the effect of firm commercialization and defensive capabilities affects buyer choice for inventors. However, it is important to note that this method measures a before-after effect as opposed to a differences-in-differences effect. The equation is as follows:

$$Pr(Y_{t,K,i} = 1|X_{t.K,i}) = \frac{\exp(\alpha_{P,t,K} + \beta_P X_{t,K,i})}{1 + \exp(\alpha_{P,t,K} + \beta_P X_{t,K,i})} + \varepsilon_{t,K}$$

Where K indicates the patent being traded in year t, and i represents the counter for the potential and actual buyers for the traded patent in the year of trade (as such, the t really applies to the i indicator). The data is organized in the following way. Each patent-year pair where a trade occurs (i.e. the year for which a specific patent is traded) is treated as a single observation. $Y_{t,K}$ is the categorical dependent variable measuring whether a trade has occurred or not. $Y_{t,K}$ is recorded as 1 when a trade occurs to a potential (or actual) buyer, and 0 otherwise. P is 1 for the period before Markman v. Westview, and 2 for the period after Markman. The regressions will be run separately for $P = 1, 2$, and the coefficient vectors $\beta_{1,2}$ tested for statistically significance differences.

$\alpha_{P,t,K}$ are measures of conditional fixed-effects arising from within-sample variations - in other words, variations that arise from factors specific to the year and potential buyers. Including this factor controls for potential trends or biases such as industry changes, patent purchasing trends, or firm reputation.

$X_{t,K,i}$ represents the explanatory variables, which include the following variables:

The primary variable of interest is the normalized patent holdings measure per potential buyer. This is measured as the potential buyer's cumulative patent count (not including expired patents or patents sold) in the patent's specific industry, divided by the median patent holdings (of patents classiffied in that industry) of all active firms with a presence in the industry. As the component of the vector β_P relating to normalized patent holdings (which we will term $\beta_{1,P}$ for convenience) increases, this indicates that the probability that a trade occurs with a buyer with higher normalized patent holdings increases. In other words, inventors choose to sell their patents to the potential buyer with higher normalized patent holdings.

Below we list other variables we include in the regression to control for various endogeneity issues and bias.

- R&D intensity, measured as the natural logarithm of the ratio of annual R&D spending to employee count. If R&D intensity is high, this may reflect a firm investing heavily in R&D. This controls for a source of omitted variable bias, as high R&D spending may cause higher rate of patent purchases from the firm, and potentially incentivizing inventors to sell to the firm due to more attractive bargaining or available capital.

- Capital intensity, measured as the natural logarithm of the ratio of net PP&E to employee count. Capital intensity may indicate to what extent the firm may be at risk of hold-up (i.e. where a firm may be unable to execute a project and realize returns because of blockages by another entity, which may be demanding rents. Patents represent a prime opportunity for hold-up as the holder of the patent can legally block another firm from capitalizing on a technology that infringes upon the patent). If capital intensity is high, then the potential downside of being held up is high, incentivizing firms to acquire patents aggressively, as suggested by Ziedonis (2004).

- Firm size, measured as the natural logarithm of employee count. This measure is included to control for omitted variable bias where a larger firm would have access to higher number of potential avenues to encounter any given patent (i.e. lowering search costs). Size also proxies for firm reputation to a certain extent, which would also lower search costs on the side of the firm. The ease of finding patents to acquire may bias inventors to sell to larger firms as they have found those potential buyers more quickly and easily.

After we run the logit on both periods, we apply the seemingly unrelated regression estimation (SURE) method (Zeller (1962)) to test whether the difference in the normalized holdings coefficient is significant across time-period subsamples.

2.5 Results and Robustness Checks

Table 5: Conditional Fixed-Effects Logit Estimates of Buyer Characteristic Determinants of Trade

Variable	Base		Robustness Checks					
			R&D Int		Cap Int		Emp	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Intercept	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff
Holdings	0.701**	0.421**	0.574**	0.364**	0.546**	0.355**	0.454**	0.310**
	(0.155)	(0.143)	(0.185)	(0.173)	(0.099)	(0.083)	(0.106)	(0.094)
ln R&D Int.	-	-	0.236*	0.273*	0.589*	0.418**	0.994**	0.773**
			(0.185)	(0.194)	(0.288)	(0.183)	(0.267)	(0.244)
ln Cap Int.	-	-			0.881	0.691	0.890*	0.649
					(0.531)	(0.428)	(0.435)	(0.361)
ln Emp	-	-					0.287	0.255*
							(0.163)	(0.112)
SURE (chi sq)	1593.29***		980.19***		848.97***		467.28***	

1. 599 observations were dropped as only the buyer had presence in technological category in window

Table 5 summarizes our regression results. The base regression, shows holdings to have a positive and significant impact upon buyer choice both prior and post *Markman v. Westview*. But the degree of holdings had a stronger impact on the probability of the transfer occuring before the ruling than afterwards, while the SURE test demonstrates that the coefficients are significantly different. The interpretation of the baseline result in the first and second columns can be interpreted as follows: before *Markman v. Westview*, a patent holder would be more approximately 2 times ($2 = e^{0.701}$) as likely to sell the patent to a potential buyer with one unit more of normalized patent holdings, and 1.5 times ($1.5 = e^{0.421}$) as likely after the ruling. These values are statistically significant, as well as significantly different. An exact interpretation of these statistics is higher patent holdings has a positive impact in both cases, but that it has a lesser impact after *Markman v. Westview*. This can only occur if the frequency of sales to firms with lower normalized patent holdings, on average, in the distribution of potential buyers. In other words, innovators were more likely to sell their patents to firms with lower patent holdings after the ruling took effect.

We run several different specifications to check for robustness, including introducing various controls. Due to the specifications of the fixed-effect logit, time-based trends, such as a general shift away from patent acquisition among larger firms, are unlikely, and time-invariant firm effects, such as brand or the presence of certain long-term personnel, are also controlled. Generally, we find that R&D intensity has a significant and positive impact upon the probability of sale, which corroborates the intuition that firms that have higher R&D intensity would acquire patents more aggressively, acquiring external technology as part of their R&D efforts. Capital intensity is also positive and significant, corroborating Ziedonis (2004), who found that firms that have higher liabilities from hold-up (i.e. larger capital intensities) would be more likely to also acquire patents aggressively. In the regression specifications including both R&D intensity and capital intensity, both Capital and R&D intensities have relatively large effects. Employee count is also positive and significant, matching the intuition that larger firms would have a higher probability of finding patents to acquire due to its network and manpower, as well as having higher reputational effects. As the control variables are introduced, the effect of holdings decreases, which suggests that they play a significant role in buyer choice for innovators. However, the estimated coefficient upon the normalized holdings variables is positive, significant, and decreases for all specifications of the regression after Markman v. Westview including all control variables.

We also estimated the regression using a two-year time window before and after Markman. We also considered different normalization methods for the patent holdings variable. We respectively divide the technological category patent holdings count by the mean and the sum of the top ten holdings in the industrial classification (firm), to test whether the difference in the normalized holdings coefficient remains significant and decreasing across time-period subsamples. The estimation is shown below in Table 6. We again find that the results are robust across different time frames and normalization factors.

Finally, we also tested a specification where alternative buyers were chosen as those firms that purchased two or more patents in the technological category of the traded patents, instead of those that purchased or filled two patents. In all specifications, again the estimated coefficient upon the normalized holdings variables is positive, significant, and decreases for all specifications of the regression after Markman v. Westview.

Table 6: Conditional Fixed-Effects Logit Estimates of Buyer Characteristic Determinants of Trade

Time and Normalization Robustness Checks

	Two-Year Window		Normalization Robustness Check				Purchased 2 or More	
Normalization	Median		Mean		Top 10 Holdings		Emp	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Intercept	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff	Fix.Eff
Holdings	0.442**	0.318**	3.469**	2.842**	147.279**	84.698**	4.463**	4.14**
	(0.156)	(0.113)	(0.097)	(0.094)	(22.57)	(12.14)	(0.055)	(0.101)
ln R&D Int.	0.791**	0.770**	0.940**	0.752**	1.110**	0.831**	0.461**	0.232**
	(0.263)	(0.189)	(0.437)	(0.030)	(0.438)	(0.430)	(0.040)	(0.056)
ln Cap Int.	0.867*	0.641	0.873*	0.645*	0.871*	0.670*	0.316**	0.244**
	(0.359)	(0.295)	(0.345)	(0.297)	(0.352)	(0.330)	(0.034)	(0.054)
ln Emp	0.200	0.249	0.254	0.244	0.367	0.333	0.157**	0.037**
	(0.113)	(0.129)	(0.285)	(0.263)	(0.324)	(0.297)	(0.022)	(0.034)
SURE (chi sq)	305.99***		151.04***		567.81***		7.88***	

1.599 observations were dropped as only the buyer had presence in technologica lcategory in window in normalization

2.487observations were dropped as only the buyer had presence in technological category in two-yearwindow

2.6 Discussion

Literature suggests that firms with greater technological capabilities derive greater benefits from external technology, demonstrated empirically by Veuglers and Cassiman (2002). While this supports the positive and significant effect upon holdings, the decreasing effect of the coefficient after Markman v. Westview may be somewhat counterintuitive for several reasons. For example, in weak property rights regimes, one may expect that firms with larger patent holdings derive greater value from a given patent, as the combined patent portfolio would render more effective defense for the underlying technology (Parchomovsky and Wagner (2005)). This may incentivize firms with larger holdings to extend larger offers to inventors. Further, weakening patent regimes may incentivize firms with valuable technologies to acquire patents aggressively to try and bolster their existing defenses, in a manner similar to that suggested by Ziedonis (2004) - firms with higher commercialization capabilities and resources may find themselves more concerned about potential expropriation yet also able to expend greater resources in patent acquisition. However, we find that inventors consistently trade their patents to firms with smaller relative patent holdings when the patent regime weakens, even controlling for time, industry, or firm fixed effects, suggesting other factors may be at work.

We consider some possible explanations. As discussed earlier, the methodology does not represent a full DID framework measuring the impact against a hypothetical "control group" scenario; rather the methodology measures changes in a before-and-after fashion. Accordingly, the results may be driven by external factors independent of those measured above - in other words, changes across time may potentially be driving the effect measured in the results. We discuss potential explanations, as well as potential methods of dealing with external factors changing over time.

One possible explanation, as described above, is provided by Ahn and Yao (2015). Economic theory suggests that in strong property rights environments, inventors will be able to appropriate a substantial portion of the value of an IP without fear of expropriation. Consequently, inventors would be incentivized to approach firms with a stronger market position (as proxied by patent holdings, which also defends the existing rents better). Ahn and Yao argues that in weak property rights environments, there is a risk of expropriation - however, inventors are able to appropriate some amount of value by threatening to defect to a competitor if expropriation occurs. According to the bargaining dynamics, inventors would be incentivized to approach firms with weaker market position, because they would be able to capture a higher level of value.

However, while the theory assumes only two potential buyers of intellectual property in the market in different property rights scenarios, this is not necessarily an accurate reflection of reality, as seen in the empirical discussion above. On the other hand, introducing higher numbers of buyers will not necessarily alter the results or reasoning. In the complete property rights case, the inventor can still employ an open bargaining framework and sell his invention to the firm that can afford to outbid all other competitors - which would be the "leader" as characterized by its ability to commercialize intellectual property rights. In the no-property rights scenario, the inventor will threaten diffusion across multiple potential buyers to bargain with the potential buyer. To maximize returns, the inventor would approach a firm that would pay greater amounts to prevent deviation. This would not be the leading firm - the leading firm would pay the highest amount to encourage deviation, so rival firms would be forced to pay greater amounts to prevent this - the bargaining dynamics are thus not significantly different whether two potential buyers exist, or higher numbers (although the rival firms paying for deviation would be required to have the capabilities to outbid the leading firm's offer). In such no-property rights scenarios, the seller would approach not the largest, but the "second-best," or at least an alternative buyer that is large enough to offer higher compensation. Lower numbers of buyers is also not necessarily highly unrealistic from the inventor's perspective, as search and exposure costs for inventors looking to their commercialization invention can be significant, causing inventors to be aware of only a small number of potential buyers.

This is a potentially significant discussion as, as seen above, actual buyers generally have significantly higher patent holdings than do potential buyers, both pre and post-Markman. This raises the concern that potential alternative buyers as described above may not be relevant from the perspective of the inventors. Post-Markman does have a higher number of alternative buyers per patent with lower average patent holdings (although this not significantly so - 5.6 to 6.0 for post to pre-Markman). From the perspective of the empirical methodology, however, this may not be an issue - if a higher number of potential alternative buyers with lower patent holdings are included, this should - on average - bias the results upwards as actual buyers have higher patent holdings, meaning a plethora of low-holdings alternative buyers would make the impact of higher patent holdings more significant. Thus, this effect provides some indirect support for the theory.

Another potential explanation is that as industries mature, firms specialize their industrial and technological focus, resulting in inventors selling to firm with fewer patent holdings as smaller, specialized firms are the ones equipped to understand the particular technologies protected by a patent. However, this is not fully consistent with the results. The specialization effect may be controlled by using the median or mean normalizer for the patent holdings. The logic is as follows: as industries specialize, average (or median) firm holdings would fall, counteracting the decrease in the holdings measure for the actual buyer. As the pattern of innovator sales choice remains consistent across the median and mean normalizations, the results suggest that specialization over time is not driving the pattern. The different normalization techniques would also control for changing definitions of technological classifications in the dataset.

The results may also be driven by firm acquisition strategies. In weaker property rights regimes, firms may place greater reliance upon trade secrets, as suggested by Anton and Yao (2005). Traded patents may therefore be less valuable, on average, and be traded to smaller firms that may require such technology, while larger firms could innovate internally or have less requirements for less valuable technology. This is somewhat supported by the average citations on the patents traded before and after Markman v. Westview, decreasing from 21.4 citations to 16.9. As citations are a proxy for patent value (Hall, Jaffe, Trajtenberg (2005)), this suggests that traded patents are indeed less valuable, on average. However, 16.9 citations is still higher than the average citation for filed patents in the industry in the timeframe, which is 2.34. Thus, traded patents are still more valuable than the average patent.

Finally, as discussed above the analysis focuses upon patent transfers as opposed to licensing agreements, which are more common. While this was partially due to availability of data, transfers are also a representative sample, to a certain extent. Licensing agreements often have transfer stipulations at the end of their term. Nevertheless, it is possible that after *Markman v. Westview Instruments*, licensing agreements were conducted for the majority of patents while a specialized subset were transferred - potentially less valuable ones the current owners were willing to relinquish. However, as the transfers are from small inventors with a diminished capacity to self-innovate, and as the data has suggested that transferred patents are valuable, this scenario seems intuitively unlikely.

2.7 Conclusion

This essay explores the impact of weakening intellectual property regimes upon the market for patents. By examining the impact upon patent buyer choice before and after the 1996 Supreme Court ruling on Markman v. Westview, we find that innovators generally choose to sell to firms with lower patent holdings after the ruling, which weakened defense against infringement. This suggests that innovators sell to firms with lower commercialization and patent defensive capabilities when the patent regime weakens. Ahn and Yao (2015) may provide a possible explanation for this pattern. This argues that bargaining dynamics for IP sales change across different intellectual property regimes, and that in weaker IP regimes innovators may be incentivized to sell to firms with lower commercialization potential because they may be able to capture higher levels of value.

The results provide several implications for innovators, firms, and policy-makers.

For innovators, the result suggests that it may be optimal to sell to firms with lower commercialization and defensive capabilities in weaker IP appropriability regimes. For firms, the result could provide context for higher transactions costs associated with acquiring external technology, and thus suggests that firms should invest more in internal R&D in weaker patent regimes. Policy-makers may use these insights to manage the implications of IP regimes depending on goals for IP diffusion and efficient IP markets.

There are several directions this research may be extended. First, this study focuses upon patent sales. However, a substantial portion of patent value is transferred via licensing, so it may be illuminating to include licensing transactions and see whether they conform to the same pattern before and after Markman v. Westview or other shifts in IP regimes. Second, it is difficult to directly test the mechanism underlying Ahn and Yao (2015), as it depends on the value that innovators can capture. If future research can gain access to the price or rents that innovators earn on their IP, this could render further insight upon IP trading dynamics and observe the direct impact of IP regimes on the market for innovation.

Chapter 3
How Do I Use This? A Conceptual Model of Patent Dynamic Capabilities

3.1 Introduction

In recent years, patents - government-granted contracts providing exclusive rights to any rents arising from a novel, non-obvious innovation - have become a critical component in competitive strategy (Chesbrough (2003), Fosfuri (2006)). They are a significant source of potential value or outlay – significant patent portfolios such as those auctioned by Eastman Kodak and Motorola are regularly valued in the billions, and the ruling of infringement in a patent lawsuit can result in the required payments of equal magnitude.

Firms have thus developed multiple ways of organizing their resources, assets, and behavior in a way to maximize the value of their portfolios (Somaya (2012)). However, patents are complex instruments, and as firm strategic goals and circumstances change, existing configurations of patent holdings can become less optimal over time. Consequently, firm patent strategy should incorporate some dynamic capabilities, allowing the firm to update its patent portfolio, as well as the strategic processes and supporting assets of those portfolios, to adapt to its strategic environment.

The purpose of this essay is to introduce a conceptual framework for understanding the processes driving dynamic firm behavior around patents by introducing granular insights from the patents literature to the concept of dynamic capabilities, i.e. "the firm's ability to integrate, build, or reconfigure internal and external competencies to address rapidly changing environments" (Teece et al. (1997)). We also apply the model within the specific framework of the technology life-cycle model to highlight the conceptual model's potential value in both generating insight into existing patent strategy as well as providing prescriptive tactics to practitioners.

The essay comes at the union of two major streams of literature: dynamic capabilities as a source of competitive advantage, a highly influential stream of thought in strategic management theory (1997); and patent management strategy, which encompasses a broad range of literature ranging from optimal patent acquisition patterns in industries with fragmented technology to strategic disclosure in weak property rights regimes (Ziedonis (2004); Anton and Yao (2002)). While previous literature have realized the significant non-market strategic value of patents, including characterizing them as a type of resource (Barney (1984)), as well as the inherent significance of dynamic capabilities in pursuing innovation as a cornerstone of competitive advantage (Teece et al. (1997), Eisenhardt and Martin (2000), Zollo and Winter (2002)), the contribution of this essay is to identify specific dynamic capabilities as related to patents, even extending beyond competition purely via innovative technology.

The structure of this essay is as follows. In Section 2, we analyze the three primary avenues by which patents provide value to firms and how optimal patent value can change depending on the patent legal and market environment and firm strategic goals. We base this section generally upon Soyama (2012). In Section 3, we develop a conceptual model of the firm's patent dynamic capabilities, composed of 1) patent evaluation capabilities, 2) patent deployment capabilities, and 3) patent acquisition capabilities, and explore how this allows firms to adaptively reconfigure its patent strategy. Section 4 applies the conceptual model to the technology life-cycle theory, developing hypotheses for optimal firm behavior in response to this life-cycle. Section 5 concludes.

3.2 Patent Value, Strategic Goals, Environmental Factors, and Alignment

It is well-understood that patents are valuable in providing competitive advantage via exclusive access to rents arising from innovative technologies. However, patents are more than merely a static source of technological rights; instead, they are dynamic, multi-faceted objects that render multiple types of value to the firm. This section describes the three primary ways that patents provide value to firms: commercialization, defensive, and leveraging value.

3.2.1 Commercialization Value

Commercialization, i.e. using a patent to prevent competitor imitation of a valuable technology, has been described as the "most powerful benefit" of patents (Rivette and Kline (2000)). The commercialization value of a patent, i.e. the traditional understanding of the patent as described above, derives from the firm's use of the direct technological innovation underlying the patent (Somaya (2012)). The novel technology allows the firm to both expand their existing technological capabilities or to develop and commercialize new technologies while protecting against imitation from competitors (Duysters and Hagedoorn (2000)). In other words, commercialization value is the competitive advantage that the firm gains in having exclusive access to valuable technology (Kitch (1977), Mazzoleni and Nelson (1998)), which can be measured directly in terms of income, or indirectly as benefiting the firm's internal processes and R&D.

3.2.2 Leveraging Value

Firms can also generate value by threatening or applying patent litigation against other firms using technology overlapping with the patent's claims. Since patents are exclusionary devices, the patent-holder can "hold-up," or prevent outside firms from profiting from products developed using the technology, particularly when commercialization of a valuable technology is dependent upon the innovation covered by the patent. At the least, the patent-holder can threaten costly litigation, which bears the risk of court rulings in favor of the patent holder (instead of the commercializer). In those cases, the outside firm would either be prevented from commercializing the product altogether (losing all investments for little return), be required to pay licensing fees, or be forced to substitute for the patent innovation. The high costs faced by the outside firm thus provides significant bargaining power to the patent-holder, who can use this bargaining power to extract value from the commercializing firms (Lemley and Shapiro (2007)) in the form of licensing fees or other strategic concessions.[8]

For example, the threat of hold-up or litigation can be used to bargain for access to the threatened firm's technology, to provide counter-suits when the patent holder has been threatened itself, or to generate other non-market strategic value (Arora and Fosfuri (2003)). Naturally, leveraging value is only available for firms that have own the patent, which raises the benefit of acquiring over licensing the patent.[9]

Leveraging is thus most valuable when the patent claims cover a significant technology used by other firms, and the costs and risks inventing alternative technologies to avoid the patent-covered technology are sufficiently high. Bargaining power for both parties in leveraging scenarios is ultimately decided by the threatened firms' expectations of the potential benefits of fighting the litigation, which can be influenced by the leveraging firm. For example, a firm with an aggressive reputation in patent settlements can signal to other firms that litigation may be a costly option (Agarwal, Ganco, and Ziedonis (2009), Waldfogel (1995)). The influence of the firm's assets upon patent leveraging value is discussed further in the section on internal firm strategic characteristics below.

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8 Non-practicing entities (NPEs), colloquially known as "patent trolls," base their strategy solely upon extracting this licensing value from firms that are commercializing technologies that relate to the patents held by the NPEs.

9 Occasionally, some licensing contracts allow the licensee the ability to enforce the patent and litigate against outside infringers.

3.2.3 Defensive Value

Leveraging and defensive value exist in counterpoint – whereas leveraging value derives from the application of the exclusionary power of patents against other firms, defensive value comes from protecting against leveraging strategies from outside patent-holders, preventing hold-up or loss of rents via licensing. Fundamentally, the need for defensive strategies arises because a patent confers only the right to exclude others, not an affirmative right to use the patented technology - as opposed to commercialization value, which provides new opportunities for firms to develop competitive advantages and technologies, patents provide defensive value when it allows firms to use their own existing technology. Firms often make significant, non-recoverable, and non-redeployable investments to develop or commercialize a technology before fully exploring how patent rights are committed, particularly in fast-paced, capital-intensive industries. Such investments render firms especially vulnerable to hold-up, making defense against outside firms especially critical.

Defensive value can be distinguished from commercialization value because 1) it can occur ex-post innovations, but more importantly 2) it is more of a countering defensive measure against the patent holdings of other firms, rather than a staking of essential commercialization technologies per se. That is, commercialization patents capture new, valuable technologies, whereas defensive measures protect the value chain from erosion from rent-seeking leveragers that can potentially hold-up the entire production process.

Consequently, the defensive value of patents is important in industries where the risk of litigation or accidental infringement is high, whether due to industrial or to market structure characteristics. For example, industries with fragmented patent rights - in other words, when ownership of patents in an industry are split between a high number of firms (Ziedonis (2004)) or when a large number of sequential or complementary innovations are required to commercialize products (such as with smartphones) the exposure to others' patents could be particularly problematic (Hall and Ziedonis (2001), Somaya and Teece (2001)). Such factors are discussed further in the section on the firm's strategic context, particularly external and market structure characteristics.

Patent defensive value is realized by various tactics to prevent external litigation. For example, firms can either patent or obtain ex ante licenses to all required inventions before commercializing (although this can sometimes be impractical due to scope, timing, and breadth of market). Firms may also preempt risky patent rights by disclosing inventions themselves (Guellec, Martinez, and Zunigac (2012)) or by preventing patents from issuing through opposition and reexamination procedures (Graham, Hall, and Harhoff (2003), Wagner (2009)).

3.2.4 Strategic Goals, Environmental Factors, and Alignment

Depending on the firm's strategic goals and the legal and patent market environment, patent value can change dramatically.

The value of a given patent is influenced by the firm's strategic context, both in terms of the firm's strategic goals and the external environment in which it operates. For instance, the firm can choose to use their competitive advantage in legal expertise to enhance the leveraging value of patents, building their strategy around extracting licensing revenue and concessions from rival firms. Other companies may instead choose to apply an advantageous market position and technological expertise to gain the maximum benefit from the commercialization value of patents, deriving the full value of patents.

The external patent environment refers to the dynamics of a given industry, including the patent legal environment, which entails the legislation and market forces that affect the ease of filing and defense of patent claims from infringement, lawsuits, and re-evaluations; and the structure of the universe of patents (or at least on an industrial level), i.e. the positioning of patent thickets and the co-dependencies of innovations. For instance, smart phones are a product containing hundreds of innovations, the patents to which are spread among multiple entities, thus requiring complex contracts and leveraging deals to allow sales and production. Individual patents can also be susceptible to reinterpretation or infringement due to "fuzziness" of technology definitions. On the other hand, pharmaceutical patents are known for their relative simplicity, covering only single compounds, their derivatives, or drug delivery systems, and due to this simplicity are generally known to be easier to defend (at least individually).

We argue that there are, broadly speaking, four primary strategies that firms can pursue with patents, corresponding to the patent value types. First is when a firm is pursuing a policy of technological superiority – i.e. using knowledge of a proprietary technology not known (or not accessible, due to patents) to competitors, allowing the firm to gain a competitive advantage in the product marketplace. This can involve both development of new competencies, or extension of older competencies into new areas (Prahalad and Hamel (2000), Silverman (1999)). For this strategy, the commercialization value of patents is particularly significant, and due to the rapidly evolving nature of such cutting-edge technologies, firms will be incentivized to pursue new patents and stake out their "turf" in the chain of innovation.

When firms have already achieved a technological advantage they may shift into a strategy of defending their existing competitive technologies – in this case, firms will find continuing value of their commercialization patents but also seek to extend the defensive value of their existing patents. This strategic situation may arise when property rights become stronger due to policy changes – as firms have less incentive to pursue trade secrets over patenting, there may be a rush to patent important extensions and applications of established technologies (as technologies that are sufficiently aged are considered prior art) and preserve them in the marketplace.

Finally, firms may pursue of strategy of leveraging their existing patents against outside firms, exactly in line with the patent's leveraging value. It can pursue non-market bargaining strategies, extracting strategic concessions in the marketplace, or simply derive high levels of licensing revenue. Such firms, as expected, rely extensively upon patent leveraging value.

Legal Environment

As patents are inherently legal instruments, the legal environment has a strong influence on their value. Depending on the legal regime, or the rules, laws, regulations, and processes regarding patent filing/registration, litigation, and defense, the strength of patent rights can be affected in a variety of ways. Patents can suffer a greater probability of being rejected outright in the application process; their claims may be broadened or narrowed either during the application process, or after issuing via re-evaluations and lawsuits. The distribution of patents across market players in a given industry has a significant impact on the value of individual patents.

When patent rights are weak, the paradox of disclosure becomes a particular issue for entities that are attempting to sell their innovation, although they have various method of preventing expropriation. Anton and Yao (1994) suggest that innovators may earn compensation by threatening diffusion of the invention to competitors, by only partially disclosing their invention (Anton and Yao (2002)), although Serrano (2010) finds that more valuable patents with higher citation counts are more likely to be traded. From the perspective of the buyer, this can reduce the value of the potential value of the underlying technology of a patent to be acquired, while simultaneously raising the cost of purchase. Combined with the weaker protection, industries with weak patent rights may find firms relying heavily instead on lead times, secrecy, and internal development capabilities, as seen in the semiconductor industry (Hall and Ziedonis (2001)). A survey administered to 1478 R&D labs in the U.S. manufacturing sector in 1994 found that firms used both patenting and secrecy more heavily when compared to the early 1980s, suggesting that firms rely on secrecy to protect product innovations and use patents to "block" rival firms from accessing valuable technologies (Cohen, Nelson, and Walsh (2000)).

Since the 1980s, the United States has undergone substantial shifts in its patent environment. Prior to the establishment of the US Court of Appeals Federal Circuit, or CAFC, district courts had managed the majority of patent infringement rulings, encouraging a certain amount of "forum shopping" where litigators approached courts known to be more supportive of patentees or infringers, depending on need (Jaffe (2000), Gallini (2002)). The CAFC consolidated patent activity into a new federal appeals court, introducing a centralized environment for patent litigation on appeals before the involvement of the Supreme Court. It is generally understood that the CAFC was pro-patent, i.e. that it typically ruled in favor of patentees instead of infringers in infringement lawsuits (Allison and Lemley (1998), Jaffe (2000), and Gallini (2002)). The CAFC upheld the validity of patents at a higher rate than prior to its establishment, although it also did curtail the scope of patent claims somewhat. On average, the CAFC represented a consolidated pro-patent regime especially compared to the wide array of appeals courts to which patent holders or plaintiffs could apply.

The higher rate of rulings for patent holders as opposed to infringers means that the commercialization value of patents rose due to the higher expected payoff due to prevention of rent erosion through infringement. Rulings in favor of the patent holder may also result in leveraging revenue. On the other hand, defensive value becomes of greater importance for firms, as being litigated for infringement has a higher risk of rulings in favor of the litigant. Acquisition of patents to prevent leveraging behavior from other firms becomes of higher importance. Finally, as discussed above, greater patent strength can, in conjunction with firm commercialization capabilities, may have resulted in lower search costs.

As of the mid-1990s the tide of the patent environment began to shift once more as the Supreme Court began to issue rulings that sharply curtailed the scope of upheld patents (Lunney (2004)). Rulings reducing the scope of patents made it easier for infringers to defend themselves in court, as they could argue they did not cover more limited claims of a given patent. These rulings, although they did not necessarily result in a higher rate of rulings for the patent holders, nevertheless reduced the scope of patent protection and thus their commercialization value.

For practitioners, the analysis of the strength of property rights should take into account industry-level effects. The effectiveness of patents depends not only on the type of technology that is protected, but also on industry-specific regulation, as well as the nature of the technology common to the industry. For example, the biotechnology and pharmaceuticals industry, for instance, is known to have more effective protection than the semiconductor industry, as the former industry's products are very difficult to invent-around or imitate, being often based on individual molecules or specific compounds (Benin (2005)). From a regulatory perspective, major court cases such as the 1998 CAFC ruling State St. Bank v. Signature Financial Group primarily affected software and algorithms, but also paved the way for patenting business methods, which allowed for a new level of protection for previously undefined "technologies.".

Industrial Patent Structure

The structure of patents in a given industry has two primary components: (1) the distribution and holdings of firms holding patents within an industry, and (2) the innovative relationships between patents, i.e. the way patent innovations depend on each other in order to be effective or commercially viable.

The distribution of patents across market players in a given industry has a significant impact on the value of individual patents. Ziedonis (2004) finds that fragmented property rights (i.e. when ownership rights for related, sequential innovations are spread across multiple owners) can cause problems for firms attempting to commercialize an innovation, as discussed above. As there are a large number of entities holding related patents, the firm has a high number of possible sources of hold up, which can significantly increase transactions costs. This can be a particular issue in industries with a high level of sequential or complementary innovation, as both horizontal and vertical patent-holders can limit commercialization activity.

This problem can become more severe when transactions costs for licensing and patent transfer are high, as otherwise firms may counter-license and grant effective technology access and allow . However, transactions costs are high when

In other words, high levels of industry fragmentation greatly increase the defensive value of patents. This is especially true when firms have high levels of capital intensity, i.e. when commercialization requires high levels of investment at a given time. Due to the expensive levels of capital required for commercialization, hold-up becomes particularly costly and defensive value accordingly higher.

The nature of innovation interdependencies also has significant impact upon patent value. Sequential innovation denotes the situation where an innovation is built upon another, previous technology such as HTML iterations, which are generally developed upon previous incarnations of HTML code and structure. Industries with high levels of sequential innovation have a higher risk of hold-up, as the innovations that are "downstream" (i.e. which derive from other, older inventions) are susceptible to litigation by those entities holding patents to upstream inventions. This problem becomes more severe when property rights are strong, as patent-holders have a higher chance of winning litigation. Patents to upstream innovations thus have a high level of both leveraging and defensive value. On the other hand, firms commercializing downstream innovations may find that upstream innovations benefit from imitation and substitution, as this allows the commercializing firm to "invent around" and substitute for the upstream invention more easily, thus decreasing the holdup and litigation costs for the downstream invention. This manner of upstream imitation thus increases the proprietary value of patents downstream (Bessen and Maskin (2009)). Wang (2008) finds that extensive patenting of upstream innovations, especially research tools, often impede additional research, impose additional costs and delays. Wang notes the example of patenting DNA fragments - known as expressed sequence tags - without knowing their function, causing considerable delays and costs to conducting further commercializable research upon those DNA areas.

3.2.5 Description of Framework

As can be seen above, the firm's estimation of patent value is heavily dependent upon what strategy it chooses to pursue, as well as the legal and market environment. Consequently, in order to properly align its internal resources with its strategy and the environment, the firm must develop several interrelated dynamic capabilities.

The first is evaluation ability, or the capacity of firms to analyze (or re-analyze) the characteristics of a patent, especially in light of updating firm goals. The second is patent redeployment ability, or the capacity of firms to reorganize and update the firm's existing patent portfolio, assets and processes to match the firm's strategy. Last is the patent acquisition ability, or the capacity of the firm to file, purchase, or license external patents through the market for innovation.

The diagram below provides an outline of how these dynamic capabilities relate to one another, the firm's existing patent portfolio, and the environment.

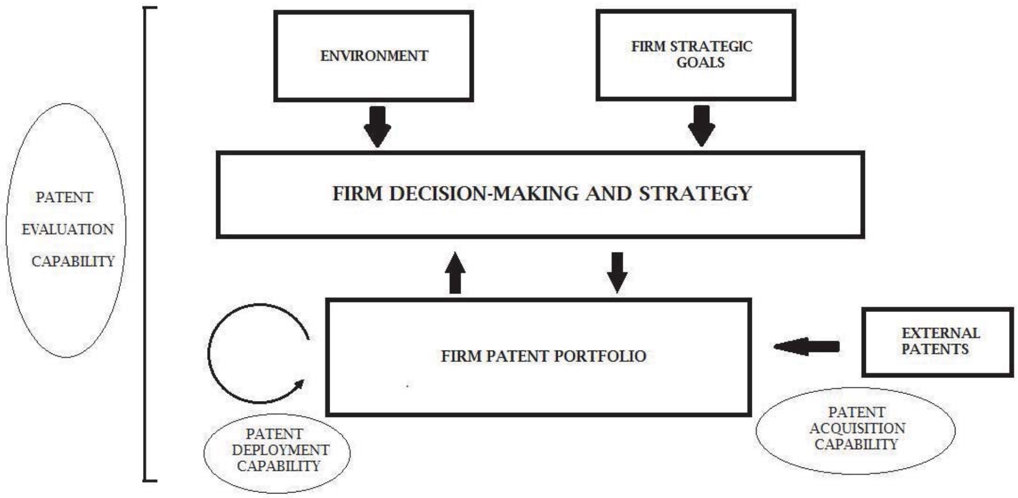

Figure 1: Patent Dynamic Capabilities Framework

The three dynamic capabilities, as can be seen, are interdependent and linked. The firm's evaluation processes provides the information necessary to make the strategic choice on acquisition or deployment – the firm's other patent dynamic capabilities then come into play and either realign the firm's resources or acquire new patents - which then enter the firm's patent portfolio and become subject to the firm's deployment dynamic capabilities in the future. The cycle repeats as firms continually re-evaluate their capabilities in changing environments.

We describe the capabilities in detail below. Before going into detail, it is important to note the unique value that patents represent when compared to the concept of a resource as traditionally understood in strategy research. Patent value is particularly dependent on the environment and the firm's other capabilities. It varies significantly due to specific regulations and the legal regimes as well as the patent holdings of competitors (as well as expiring within a given time frame), and while they are transferrable they can be utilized in unique ways depending on the firm's other resources (for example, to patch a specific hole in the patent portfolio or stake out a commercial claim for a valuable pivot for the firm's existing resources). However perhaps most importantly, unlike other typical resources, patents are an exclusive mechanism, and thus prevent competitors from commercializing certain areas, conferring competitive advantage by absence.

3.2.6 Patent Evaluation Capability

A firm must constantly be updating its awareness of its patent portfolio and the patent market and legal environments, linking understanding of the full values of its patent portfolio with the demands of the firm's strategic goals in the marketplace. These coordinative processes will allow the firm to properly comprehend what would be required of its patent portfolio and whether it needs to acquire new patents in aligning the firm's mission with the stresses of the changing environment.

Conceptually, this is linked to learning mechanisms described by Zollo and Winter (2002) – the accumulation of experience and the articulation and codification of knowledge allowing the firm to hone their organizational routines. However, the current conceptualization of patent evaluation requires a more active strategic input from the firm, as the ability to absorb and analyze external information would be itself embedded in organizational routines and thus become a dynamic capability in and of itself. Patent evaluation dynamic capability requires the development of company skillsets and processes in gathering and processing information, both internally and externally.

Firms will likely develop this capability over time, i.e. "learning-by-doing" as they compete within their respective industries, and develop their knowledge processing abilities. At the input stage, the firm must engage in appropriate sensemaking to process the plethora of information on the firm's patent portfolio as well as the surrounding environment, (Weick (1995)) while recognizing new, emergent patterns (Mintzberg (1989)). The firm must then validate, analyze, codify, present, and provide access to the information to the rest of the firm (Dawson (2000)).

While these represent general knowledge-processing capabilities, when applied to patents, this knowledge takes four primary forms: knowledge of the firm's existing patent characteristics and underlying technology, knowledge of legal processes and requirements surrounding maintenance and defense of patents, knowledge of the market's technological developments, and knowledge of competitors' patent holdings. Understanding patent characteristics requires familiarization with patent indicators such as citations, claim construction, know-how, as well as interpreting the fundamental underlying technologies. For the second category, firms should develop understanding regarding litigation, defense during patent approval and re-issuings, potentially by developing an internal legal team or contracting with an external legal firm. Knowledge of the third category may develop over time as firms continue to compete in various technological paths. For the last category listed above, firms will have to develop familiarity with the critical patent holdings of competitors in major markets, learning which outside entities hold potentially critical patents and where they are vulnerable in turn to leveraging strategies. This may occur over time as firms develop cross-licensing agreements as they debut new technologies and products - a fairly common occurence in industries such as consumer electronics (e.g. smart phones).

To this end, firms may wish to invest in a "patent center" of sorts, which will specialize in analyzing the market and the relationship of its portfolio with the evolving market of technologies and products. The knowledge-gathering and analyzing process is constant, and thus firms may find it advantageous to pursue specific knowledge management initiatives or expert systems, where expert knowledge is siloed and captured in specific groups (Dawson (2000)). Dow Chemical, for example, began its knowledge management initiatives by attempting to leverage its existing patent portfolio, while Microsoft maintaines an intellectual property and licensing center. Such patent centers would also serve as a center to use such knowledge and develop routines to file, register, or litigate patents. These patent centers will also be discussed further in the section on patent deployment capability.

These general knowledge-processing routines should be applied in understanding both the shifts in the external environment – the behavior and strategies of competing firms, the emergence of new, vital technologies, and changing legal regimes, Supreme Court rulings, regulation, etc. – and then re-evaluating the existing patent portfolio in light of these changes. When the firm comprehends the potential value of its patent portfolio and the best way it can advance the firm's strategy in the environment, the firm must then make a strategic choice whether to acquire new patents, attempt to restructure the firm's processes and assets to enhance specific aspects of the patent value, or both. Another issue is the uncertainty surrounding the true commercial value of a patent's innovation prior to acquisition (Anton and Yao (2002)). Unproven technologies bear the risk of becoming commercially unproductive, which can deter firms from sourcing external technology when they are in their initial development stage (Utterback and Abenathy (1975)). The firm's evaluation capabilities would require a careful analysis of the risks involved in acquiring the patents to any unproven technologies.

Consequently, the firm's patent evaluation ability determines the extent to which the firm has the information to make optimal strategic decisions.

Patent Deployment Capability

Upon evaluating its current capabilities and the environment, the firm must formulate its strategy and decide whether patents need to be redeployed, or new patents need to be acquired.

If the firm chooses to refresh its patents by extracting different types of value, it will have to rely upon its patent deployment capability. This extends beyond the reorganization or using old patents which may have fallen into relative underuse –

rather, the firm will have to refresh its own assets, knowledge, and processes to extract different types of value from an otherwise familiar patent. The organizational routines the firm develops to allow this kind of switching would form the foundation of the firm's patent deployment dynamic capability.

Specifically, extracting the commercialization value of patents requires the firm to develop their technical and production capabilities to exploit the patent's underlying technology. The firm will have to develop both the products using the underlying technology as well as the mechanisms, processes, know-how, and production capability to successfully manufacture and sell such productions. Given that patents are technically public disclosures of such technology, commercialization is generally the initial value derived from patents (as otherwise the technology will gradually become obsolete due to its life-cycle). Generally commercialization capabilities would be developed in tandem with the underlying technology, and though statistics indicate that 50 percent of patents are never commercialized (Morgan et al. (2001)), studies suggest that firms with higher investment in developing the technology (i.e. more spent on R&D) would be more likely to commercialize (Svensson (2007)). However, it is important to emphasize that this model explores specifically the dynamic commercialization deployment capabilities – that is, how firms develop the processes and routines allowing it to quickly shift its resources and redeploy its assets to either commercialize new technologies, or to extend existing core competencies to new patent-protected markets instead of focusing on a single production path.

Maximizing the leveraging and defensive value of patents is dependent on knowledge of the capabilities and vulnerabilities of the firm's competitors or other outside companies. While this falls under the purview of patent evaluation abilities as discussed above, it is of particular importance in pursuing leveraging and defensive strategies. One primary mechanism by which the firm will maximize its patent value is by expanding its legal capabilities, which entails gathering legal knowledge and expertise, expert personnel, and developing processes to allow for efficient patent filing, litigation, defense, hearings, appeals, etc. Such processes, which are generally somewhat separate from the operations of a product or technology-based firms, will likely need to be contained in the patent center as discussed above. The other additional primary mechanism to maximize leveraging and defensive value derives from knowledge of the strategic environment, i.e. its competitors, allies, related technologies, etc. A firm with stronger legal capabilities and knowledge of competitors' weaknesses in its defense of its innovations, as well as awareness of competitors' own patent holdings (which will allow it to litigate the firm and possibly subject it to hold-up) will aid the firm both in gaining leveraging value as well as understanding the optimal way to defend against potential leveraging strategies from others.

A broad, deep patent portfolio can be advantageous in this situation, as it provides a wide variety of bargaining "chips" to use in negotiating with competitors, and again the firm's patent knowledge dynamic capabilities will confer significant advantages in allowing firms to discover critical bargaining points and areas to "lever" while negotiating. An extensive patent porfolio also confers defensive advantages to the firm, reducing areas that outside firms can pressure (Ziedonis (2004)). Finally, firm reputation can have a significant effect - for example, a firm with a reputation as being particularly litigious can dissuade competitors from engaging in competitive bargaining or staking a claim in technology areas where firms have significant patent holdings.

As discussed earlier, these strategies can be distinguished from the allocation of resources towards R&D or technological acquisition, especially by the nature of patents as exclusionary devices. The acquisition and deployment of patents allows firms to maintain an legally defined exclusive use of a technology or grant bargaining power due to the potential threat of litigation over exclusion. As such, the competitive advantages of the strategies listed arise out of exclusion or pressure against others, as opposed to granting an intrinsic advantage due to technological capabilities, which can be developed separately. Technological development and patents can thus not be considered separately, but the nature of the advantages are separate. The unique value of patents also allow for firms that can use them separate from technologies, namely non-practicing entities or patent trolls.

Interestingly, the firm can enhance the all types of value of a given patent by acquiring additional ones. A patent portfolio has numerous synergistic benefits. Complementary rights can help provide patent coverage of a multi-innovation spanning product, while overlapping rights can bolster the defensive value against patents held by rival firms. Wider patent portfolios also give a greater range f potential leveraging options against competitors, with more opportunities to pursue litigation along different avenues. In addition, a greater knowledge base, reflected in patent portfolios, Veuglers and Cassiman (2002), who argue that investment in internal

Patent Acquisition Capability

When the firm decides that it currently lacks the patents to pursue its strategic goals, it relies upon its patent acquisition capabilities to either file new patents, or find, purchase, or license external patents in the market for innovation. Once again the firm must apply its evaluation capabilities to the patent market to understand the potential costs and difficulties it would face in acquiring new patents. Patent acquisition capabilities thus refers to the extent to which the firm can quickly and effectively locate and secure required patents not currently held by the firm.

There are two primary avenues by which firms acquire new patents: filing them or acquiring them in the market for innovation. When filing, the firm would apply its legal and technological expertise to construct the patents claims and language in a way that would render it most effective in terms of its likelihood of standing in court as well as having breadth of claims.

The firm's external patent acquisition capabilities depend upon the firm's processes and routines for searching for new patents in the marketplace, bargaining with potential sellers, and finally its absorptive capacity (Cohen and Levinthal (1990)) - i.e. the firm's ability to absorb external innovations and technologies.

Finding valuable patents can be expensive and time-consuming, potentially rendering it impractical to locate all relevant patents before investing product development based on a particular innovation (Gans, Hsu, Stern (2008)). Such search costs are especially significant in fast-moving industries where first-mover advantages are especially valuable, although development of the firm's patent knowledge capabilities above will potentially result in a significant reduction of such search costs. Certain firm characteristics, depending on environmental factors, may render advantages in this area beyond its specialized dynamic capabilities – Ahn, Anton and Yao (2015) suggests that firms with higher commercialization capabilities may benefit in strong patent rights industries by rendering them more attractive to approach from external innovators, with similar benefits according to firms with weaker commercialization capabilities in industries with weaker patent rights. Although beyond the scope of this essay, this can have interesting implications for investment in firm dynamic capabilities according to the defined conceptual structure, suggesting that firms may gain extra benefits from pursuing leveraging and defensive strategies in weaker property rights scenarios.

Purchasing the patent is also non-trivial and requires development of the firm's bargaining capabilities, although to a certain extent this depends upon market factors and bargaining power. While firms can enhance their negotiating capabilities, both the buyer and the seller of a patent can incur significant costs in effecting a sale. If the buyer has already committed significantly to the technology, they are in a weak bargaining position, which could raise bargaining costs on the buyer's side. On the other hand, sellers bear the risk of having their intellectual property expropriated due to the paradox of disclosure, where verification of the intellectual property's value requires disclosure of the underlying innovation - the buyer could then conceivably use the idea without compensating the potential seller.

A large patent portfolio can again be advantageous in this situation - in addition to conferring bargaining chips as argued above, the scope of the patent portfolio naturally renders awareness of a wider array of technologies, reducing search costs. An extensive portfolio also reflects a deep technological knowledge base, which also confers benefits to the firm's absorptive capacities. The benefits of internal R&D and internally held technologies has found empirical support as well (Veuglers and Cassiman (2002)). In certain cases, firms acquire or divest large patent portfolios, particularly in emerging industries where the value of certain technologies are as yet unclear, and consequently also the value of patents covering such technologies.

Firms with a reputation as being friendly for innovators can find this beneficial in acquiring external technologies as it attracts intellectual property holders, although small innovators may actually have a difficult time observing such reputations (Gans and Stern (2002)).

While the analysis so far has focused upon the patent acquisition decision, when firms are pursuing technological commercialization strategies, they may find it preferable to license the technology underlying a patent (held by another firm) instead of purchasing or "inventing around" existing technologies. This may be due to several reasons - for instance, the current patent holder may be unwilling to relinquish ownership, or set the cost of purchase is prohibitively high. In fact, depending on how prohibitive the transactions costs are for determining licensing agreements (factors of which include the ease of expropriation, the ease of litigation, the extent to which the patent regime is pro-patent holder, as well as firm-specific bargaining characteristics), firms may find it more commercially viable to leverage existing value chains and capture value via technology rather than competing head-to-head. Netscape, for instance, initially considered a technology licensing relationship with Microsoft before committing to competing directly with Microsoft's Internet Explore browser. A number of firms in the pharmaceutical space also focus specifically upon licensing their drug delivery technologies, such as Penwest Pharmaceutical's TIMERx delayed-drug delivery system.

On the other hand, while licensing grants access to the underlying technology, usually at the cost of some royalties, it does not typically grant ownership privileges unless otherwise specified. Patent licensees, therefore, typically lose access to the leveraging value of patents and to a certain extent, defensive value. Further, the licensee bears the risk that the licensor may terminate the contract and holdup the licensee's rents, or that the licensor may license the same technology to competitors, resulting in imitation that cannot be litigated. Court rulings on patent infringement cases also sometimes result in licensing agreements with reasonable royalties (Anton and Yao (2007)).

Consequently, licensing provides commercialization value and to a certain extent, defensive value (which is also diminished - the defensive legal responsibilities typically remains with the patent-holder), but leveraging value is low.

3.2.7 Patent Dynamic Capabilities and the Technology Life Cycle

We extend the above framework with the theory of the technological life-cycle, pioneered by Henderson (1995). The technology life-cycle theory argues that all technology follows a four-stage process (also known as the technology "S-curve"). After an initial period of R&D where the innovation is an investment sink rather than a source of value, the technology enters the ascent phase, where initial costs are recovered and the technology begins to gather acceptance and implementation. Eventually the technology reaches the maturity phase, where it is readily actionable and often spread through the marketplace – it is a key value driver. Finally the technology declines as the innovation becomes outdated and the technology gradually uses its utility.

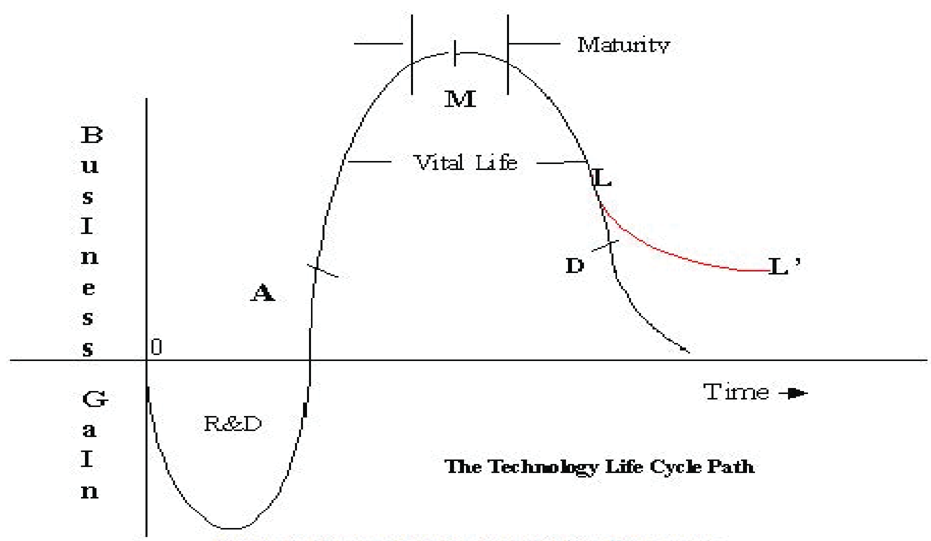

Figure 2: Patent Dynamic Capabilities Framework

Figure 2 provides the visual depiction of the technology life-cycle and the S-curve, sourced from en.wikipedia.org/wiki/Technology_life_cycle.

This general concept has seen much traction within the management and strategy literature. Klepper (1996) describes a similar life-cycle among products, which are often driven by such technologies, whereby competitors gradually adopt a product at an increasing pace until competition drives out high-cost producers into maturity (and the product becomes outdated). When extended to an industrial scale, we see a generally similar process, described as "punctuated equilibrium" by Tushman and Anderson (1986). When groundbreaking technologies first emerge, they are followed by a wave of increasing incremental innovations that gradually peter out until the next breakthrough. We can generally understand that industries built around technologies generally follow the same cycle of development, growth, peak, and decline.

Conjecture 5 In rapidly changing technological regimes, including deepening of the technological chain of dependencies (i.e. upstream and downstream innovations) commercialization value is particularly significant for product-developing firms. Acquisition dynamic capabilities are favored.

In rapidly evolving technological regimes (e.g. immediately after the development of a breakthrough technology, or in the growth phase of a technology or industry), firms in the market compete with one another to capture new technologies and "stake their claims" using patents. Particularly as fundamental innovations are developed and the chain of future innovations begins to build upon these, acquiring patents for critical upstream technologies becomes essential for maintaining a competitive advantage as the industry develops further. Consequently, firm efforts will be focused upon acquiring new technologies and their patents. Strategic behavior would thus emphasize the patent acquisition dynamic capability. [10]

Conjecture 6 In industries with changing patent market structure, particularly with patent thickets, fragmentation the importance of defensive and leveraging value rises. Deployment and acquisition are both favored, with acquisition more favored for larger firms.

When industrial changes are not being driven by rapid technological progress, the firm's competitive advantages are driven less by claiming patents to critical technologies. Rather, firms should shift their strategies to focus upon bolstering their defense and improving their bargaining position vis-à-vis external firms.

Especially when patent market structure is changing, the firm will respond by evolving its existing patent portfolio. Given an industry-level change in patent regulation, firms can potentially acquire new patents en masse via acquisitions or portfolio auctions. However, most firms may find this activity prohibitively expensive and thus pursue optimizing the value of its patent base by applying their deployment dynamic capabilities.

In such settings we should therefore expect to see greater emphasis upon ex-

[10] These environments also provide, of course, ample opportunities for patent trolls, who may also scramble to acquire patents to litigate the other, product development firms. For these firms, acquisition would also be the strategic focus.

tracting defense and leveraging value, emerging from a combination of acquisition and deployment dynamic capabilities, especially among smaller firms.

Based on these two conjectures, we develop a hypothesis for shifting dynamic capabilities over the product life cycle as follows:

Conjecture 7 Firms' patent dynamic capabilities gradually shift over time from acquisition to redeployment capabilities. (However patent evaluation capabilities remain always relevant)

Over time, as technologies evolve and mature into the life cycle, industry structure and thickets eventually become "calcified" around existing technologies. As the rate of new technologies taper off, firms begin to compete by applying their given patent portfolios in bargaining, defense, and leveraging. Consequently, there over the course of the technological (or industrial) lifecycle, there is a continual iterative process of reevaluating existing patents and a gradual shift from commercial to defensive and leveraging strategies.

We should therefore expect to see greater investment in litigation and deployment dynamic capabilities – or rather, that firms with such capabilities compete more successfully over time instead of those that invested only in acquisition capabilities. This may especially be true for established firms in the marketplace developed around "fundamental" technologies when the market was initially established (or disrupted) - such firms are especially dependent on their patents to maintain their advantages. Some firms - for example firms that operate providing specific services to other established, technologically based-firms, or firms that develop specificied, narrow downstream technologies may still find that commercialization strategies are favored, or otherwise not necessarily altogether.

Once again it is important to note that the driver of this shift in strategically optimal firms is the evaluation capabilities. Firms that are able to discern the evolving nature of the market and its innovations would be in a position to alter its strategy according to the times – however, it is dependent on the firm's applicatory (acquisition and deployment) dynamic capabilities to actually transform the firm's resources into properly using its patents.

3.3 Conclusion

This essay develops a conceptual framework to describe the framework by which firms can develop dynamic capabilities and optimize their patent portfolio value in response to its changing goals and its environments. Critically, this is dependent upon the insight that patents have multiple types of value – their strategic value evolves over time, and firms sho uld be aware of this and respond accordingly.

The conceptual model makes several potentially valuable contributions. First, it provides some insight into how firms can develop various internal processes to develop the firm patent's dynamic capabilities. Dynamic capabilities, while generally acknowledged to be a deep and valuable insight into the reasons behind the continuing competitive dominance of certain firms, is sometimes criticized for being potentially tautological or that it does not provide deeper, more specific insights. By introducing insights from the patents literature, including discussions on the different ways on which patents provide value and how they are affected by the environment, we are able to suggest more granular processes that would actually comprise a firm's dynamic capability, as well as suggesting the different categories in which it can manifest. We also extended it using the technology life-cycle theory, providing a potentially testable theory or prescriptive path of development for practitioners.

Future research may potentially find it beneficial to extend the model further by introducing greater depth into the currently high-level notion of firm strategic goals. For instance, we may be able to apply Porter's generic strategy (Porter (1980)) to discover the different ways in which the different patent dynamic capabilities come to the fore – or further, to develop even more specific descriptions of a firm's patent dynamic capabilities. Ideally the theory should be connected with practice, corroborating insights and predictions with evidence and explanations from practitioners.

References

[1] Ahn, Pyoungchan J. and Dennis A. Yao "The Dynamics of Intellectual Property Sales and Property Rights Regimes." Working paper, Harvard Business School (2015)

[2] Allison, John R., and Mark. A. Lemley. "Empirical Evidence on the Validity of Litigated Patents." *AIPLA Quarterly Journal* 26.3: 185-275

[3] Anton, James J., and Dennis A. Yao "Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights." *The American Economic Review* 84.1 (1994): 190-209

[4] Anton, James J., and Dennis A. Yao. "The Sale of Ideas: Strategic Disclosure, Property Rights, and Contracting." *Review of Economic Studies* 69.3 (2002): 513-31.

[5] Anton, James J., and Dennis A. Yao. "Little Patents and Big Secrets: Managing Intellectual Property." *The RAND Journal of Economics* 35.1 (2004): 1

[6] Argote, Linda, Bill Mcevily, and Ray Reagans. "Introduction to the Special Issue on Managing Knowledge in Organizations: Creating, Retaining, and Transferring Knowledge." *Management Science* 49.4 (2003)

[7] Arora, Ashish, and Andrea Fosfuri. "Licensing the Market for Technology." *Journal of Economic Behavior & Organization* 52.2 (2003): 277-95.

[8] Arora, Ashish, Andrea Fosfuri, and Alfonso Gambardella. "Markets for Technology: The Economics of Innovation and Corporate Strategy". Cambridge, MA: MIT, 2002. Print.

[9] Arrow, Kenneth. "Economic Welfare and the Allocation of Resources for Invention." *The Rate and Direction of Inventive Activity: Economic and Social Factors.* Princeton, NJ: Princeton University Press, 1962. 609-626. Print.

[10] Bronwyn H. Hall, Adam Jaffe and Manuel Trajtenberg. "Market Value and Patent Citations." *The RAND Journal of Economics* Vol. 36, No. 1 (Spring, 2005), pp. 16-38

[11] Cassiman, Bruno, and Reinhilde Veugelers. "R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium." *American Economic Review* 92.4 (2002): 1169-184.

[12] Cohen, Wesley M., and Daniel A. Levinthal. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35.1 (1990): 128.

[13] Cohen, Wesley, Richard Nelson, and John Walsh. "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)." Working paper, NBER (2000)

[14] Duysters, Geert, and John Hagedoorn. "Core Competences and Company Performance in the World-wide Computer Industry." *The Journal of High Technology Management Research* 11.1 (2000): 75-91.

[15] Encaoua, David, and Yassine Lefouili. "Choosing Intellectual Protection: Imitation, Patent Strength and Licensing." *Annales d'Economie et de Statistique*, 79: 241-271.

[16] Fischer, Timo, and Jan Leidinger. "Testing Patent Value Indicators on Directly Observed Patent Value—An Empirical Analysis of Ocean Tomo Patent Auctions." *Research Policy* 43.3 (2014): 519-29.

[17] Galasso, Alberto, Mark Schankerman, and Carlos J. Serrano. "Trading and Enforcing Patent Rights." *The RAND Journal of Economics* 44.2 (2013): 275-312.

[18] Gallini, Nancy T. "The Economics of Patents: Lessons from Recent U.S. Patent Reform." *Journal of Economic Perspectives* 16.2 (2002): 131-54.

[19] Gans, Joshua S., and Scott Stern. "The Product Market and the Market for "ideas": Commercialization Strategies for Technology Entrepreneurs." *Research Policy* 32.2 (2003): 333-50.

[20] Greene, William H., and R. Carter. Hill. "Maximum Simulated Likelihood Methods and Applications". Bingley, U.K.: Emerald, 2010. Print.

[21] Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg. 2001. "The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools," NBER Working Paper No. 8498.

[22] Hall, Bronwyn H., Adam Jaffe and Manuel Trajtenberg. "Market Value and Patent Citations." *The RAND Journal of Economics* Vol. 36, No. 1 (Spring, 2005), pp. 16-38

[23] Jaffe, Adam B. "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process." *Research Policy* 29.4-5 (2000): 531-57.

[24] Lerner, Josh, and Jean Tirole. "Efficient Patent Pools." *American Economic Review* 94.3 (2004): 691-711.

[25] Lerner, Josh, and Robert P. Merges. "The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry." *The Journal of Industrial Economics* 46.2 (1998): 125-56.

[26] Linden G., Somaya D. 2003. "System-on-a-Chip Integration in the Semiconductor Industry: Industry Structure and Firm Strategies." *Industrial and Corporate Change*, 12: 545-576.

[27] Lunney, Glynn S. "Patent Law, the Federal Circuit, and the Supreme Court: A Quiet Revolution." *Supreme Court Economic Review* 11 (2004): 1-80.

[28] Mansfield, Edwin, Mark Schwartz, and Samuel Wagner. "Imitation Costs and Patents: An Empirical Study." *The Economic Journal* 91.364 (1981): 907.

[29] Moore, Kimberly A. "Judges, Juries, and Patent Cases: An Empirical Peek Inside the Black Box." *Michigan Law Review* 99.2 (2000): 365-409

[30] Moore, Kimberly A. "Markman Eight Years Later: Is Claim Construction More Predictable." *Lewis and Clark Law Review* 9.1 (2005): 231-247

[31] Reitzig, Markus. "What Determines Patent Value?: Insights from the Semiconductor Industry." *Research Policy* 32.1 (2003): 13-26.

[32] Sease, Edmund J. "Markman Misses the Mark, Miserably." *University of Illinois Journal of Law, Technology, and Policy* 2004.1 (2004): 99-104

[33] Serrano, Carlos J. "The Dynamics of the Transfer and Renewal of Patents." *The RAND Journal of Economics* 41.4 (2010): 686-708.

[34] Serrano, Carlos J. "The Market for Intellectual Property: Evidence from the Transfer of Patents," Working paper, University of Toronto. (2005)

[35] Shane, Scott, and Deepak Somaya. "The Effects of Patent Litigation on University Licensing Efforts." *Journal of Economic Behavior and Organization*, 63: 739-755.

[36] Shapiro, Carl. "Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting." Innovation Policy and the Economy. Vol. 1. Cambridge, MA: MIT Press, 2001. 119-50. Print.

[37] Somaya, Deepak. "Patent Strategy and Management: An Integrative Review and Research Agenda." *Journal of Management*, 38 (2012): 1084-1114.

[38] Stern, Scott. (1995), "Incentives and Focus in University and Industrial Research: The Case of Synthetic Insulin," in N. Rosenberg (ed.), "Sources of Medical Technology: Universities and Industry". Washington D.C., U.S.A: National Academy Press, 1995. 157-187.

[39] Teece, David J. "Strategies for Managing Knowledge Assets: The Role of Firm Structure and Industrial Context." *Long Range Planning* 33.1 (2000): 35-54.

[40] Teece, David J. "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-How." *The Economic Journal* 87.346 (1977): 242.

[41] Teece, David J. "Transactions Cost Economics and the Multinational Enterprise An Assessment." *Journal of Economic Behavior & Organization* 7.1 (1986): 21-45.

[42] Teece, David J., Gary Pisano, and Amy Shuen. "Dynamic Capabilities and Strategic Management." *Strategic Management Journal* 18.7 (1997): 509-33.

[43] Tushman, Michael L., and Philip Anderson. "Technological Discontinuities and Organizational Environments." *Administrative Science Quarterly* 31.3 (1986): 439.

[44] Ziedonis, Rosemarie Ham. "Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms." *Management Science* 50.6 (2004): 804-20.